DIRECTOR OF GARRISON INSTRUCTION INDIA
7 NOV 74

PRACTICAL
MILITARY SURVEYING

AND

SKETCHING,

WITH THE USE OF THE COMPASS AND SEXTANT,
THEODOLITE, MOUNTAIN BAROMETER, &c.

CONTENTS:

MILITARY SKETCHING AND SURVEYING, WITH AND WITHOUT INSTRUMENTS,
FINDING HEIGHTS AND DISTANCES, FINDING LATITUDE AND LONGITUDE,
MILITARY RECONNAISSANCE AND PLAN DRAWING.

BY LIEUT.-COL. DRAYSON, R.A.,
ASSISTANT-INSTRUCTOR IN SURVEYING, ETC., ROYAL MILITARY ACADEMY
INSTRUCTOR IN TOPOGRAPHICAL DRAWING, ETC.,
TO THE ROYAL ARTILLERY.

NO.
OFFICE OF
DIR. MILY. EDUCATION IN INDIA.
Simla,

FOURTH EDITION.

LONDON:
CHAPMAN & HALL, 193, PICCADILLY.
1872.

UNITED SERVICE INSTITUTION
OF INDIA, NEW DELHI
LIBRARY
Acc. No. M-608
Dated 15-09-04

C 356.27

D RA-1D

DALZIEL BROTHERS, CAMDEN PRESS, LONDON.

3,705

10.12.84

PREFACE.

In the following pages a simple description will be found of the shortest methods of making a Military Sketch or Survey.

It is assumed that the reader is entirely unacquainted with the subject, and has no personal instructor at hand, consequently the plainest language has been used, so that he may readily understand the use and application of the various instruments.

This book is merely intended as an elementary work on Surveying, or as a guide to those who, having but little time at their disposal, still desire to be able to make a military sketch.

Much valuable information and aid, in the formation of the book, has been given me by Captain Binney, Royal Engineers, to whom my best thanks are due.

WOOLWICH.

INTRODUCTORY REMARKS.

MILITARY SKETCHING OR SURVEYING.

The object of a military sketch or survey, is to obtain on paper a representation of any portion of country.

A military sketch differs from a regular survey, in one or two particulars, the principal of which are, the less attention to exactitude, and the greater attention to the military features, such as the slopes, and directions of hills; the nature of rivers, woods, or other objects which might affect the movements of troops.

All surveys, or sketches, are conducted upon nearly the same principles, the difference consisting chiefly in the style of instruments used in the work, and the amount of attention given to the various details.

It might be supposed that in almost all civilized countries maps could easily be procured, by which a line of road, or a portion of country might be studied. In some instances military plans may be obtained, which might serve as

a guide to a General officer; but none of these might be on a sufficiently large scale, or the hills might not be shown, or the plan might be very incorrect, or since its construction buildings, forts, or woods, might have been added on the land. Thus, even if a map of a country should exist, this map might still not be that representation of the ground which would be required before moving, or sending troops, into a particular district.

In an enemy's country a map might not be obtainable, and in some wild countries, such as portions of Southern Africa, and Australia, military maps have not as yet been fully compiled. Thus there are many reasons why officers, and travellers, should make themselves competent to sketch, and make a plan of portions of ground.

CHAPTER I.

TO MAKE A SKETCH.

FIRST STEPS.

If required to make a sketch of any portion of a country, an individual should proceed to the most elevated locality at or near the ground, and from which the best view of the surrounding country could be procured. He would thus obtain a general idea of the surface, and could bear in mind the principal points, and also the general direction of that special portion to which his attention should be directed. He should next select some convenient piece of level or even ground, over which he could pace, or measure several hundred yards, without encountering obstacles, such as houses, rivers, or woods, and from which ground some of the principal surrounding objects could be seen; these preliminary steps might be taken in a few hours, and if the individual were mounted, in even less time, after which the details of the work may be commenced.

GENERAL PRINCIPLES.

In all surveys and sketches, it is usual to commence by measuring a base line, and then to take

angles from both ends of this base to the various prominent objects, on the ground which we purpose to sketch. These objects may be the spires of churches, the chimneys of houses, flagstaffs, posts, gates, the stems of remarkable trees, &c., all of which when correctly determined, serve as stations from which to start, when the details of the sketch are carried on.

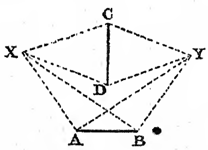
When conducting a military sketch it is the best method to place the work on paper, and in the form of a plan, when in the field. Thus, an individual should be provided with a sketching portfolio, some sheets of thin sketching paper, a pencil, a protractor for setting off angles, and either a compass or sextant for taking them. The method of observing and plotting the angles will be fully explained at a future page. The scale upon which the sketch is to be plotted should also be previously arranged, and thus the length of the base, and the relative distance of the various objects, could be at once placed upon paper.

THE BASE LINE.

The accuracy of all surveys depends mainly upon the correct measurement of the base line, which consequently should be performed with the greatest care, if a correct survey be required, and should be paced once, or twice, if a correct military sketch is called for.

When selecting the ground for a base line, we should if possible choose a piece which is level, free

from obstruction, and from both ends of which the principal surrounding objects may be observed. For a survey of about six miles square, the base line ought to be at least a thousand yards in length; and this distance should be extended by means which will shortly be explained. If, however, a level piece of ground of this extent cannot be found, we should select two prominent points from which the surrounding objects may be seen, and which are even further apart, and the distance between them may then be determined by a shorter base, and angles from the ends of this—



Thus if X and Y were suitable points from which to take angles around the country, but the whole distance between which it was inconvenient to measure, we might select any suitable ground, such as A B or C D, even in a valley, and then by means of angles such as A B Y, A B X, B A Y, B A X, or D C Y, D C X, X D C, Y D C, we should be able to determine the distance X Y, which would serve as a fresh base.

For merely a military sketch, to be made with the aid of the compass and sextant, it is not usual to employ first-class measuring instruments to obtain the length of the base line. The most common method to obtain the distance is by pacing, each individual having carefully tested at a measured distance the average length of his pace. The usual

marching pace of thirty inches is generally adopted; and when not otherwise named, a scale of paces means a scale of thirty inch paces. Thus, 360 paces would be equivalent to 300 yards. It is very easy however to test the length of one's pace, and to represent the scale accordingly.

When greater accuracy is required than could be obtained by pacing, steel chains are used, as also glass and deal rods, and when minute accuracy is desirable, Colby's compensation bars are considered the best instruments.

The steel chains are either the common Gunter's chain, which is sixty-six feet in length, and divided into 100 parts called links, or the 100 feet chain. Either of these is suitable for base line measurements, and will enable an individual to determine with tolerable correctness the length of his base line.

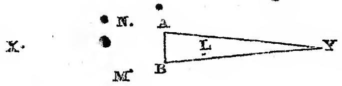
The glass and deal rods, as also the compensation bars, are more suitable for a regular survey than for a military sketch, and therefore no further details will here be given of the method of using them, or of their construction.

THE ANGULAR MEASUREMENTS.

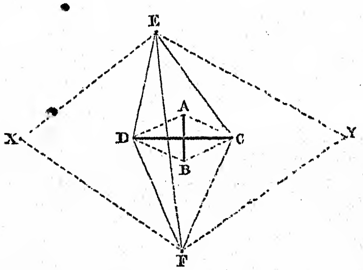
Having determined upon the direction of the base line, it may be found convenient to take the angles from one end of the base, before we leave that spot, for the purpose of measuring, or pacing, the distance.

It is a rule in all surveying that angles should not be

taken to any objects which would entail an acute intersection (of less than 40°) of two lines at that object. Thus, if X and Y were two distant objects,



and A B the measured line, it would not be prudent to attempt to determine the position of X, and Y, by means of angles taken from A and B, because the lines A Y and B Y form an acute intersection at Y. Such stations as L M N might be determined from A and B, but when distant points such as X and Y are required to have their positions fixed, it is usual to select two points,



such as C and D, on each side of the base, where acute intersections will not occur. These points being determined, two other and more distant points, such as E and F, may then be selected, and the positions

of E F being determined by means of angles taken from C and D, we can then take angles to any distant points such as X and Y, from E and F, and thus determine the position of these, and yet avoid acute intersections.

When it is requisite to extend the triangles, this plan is found to be far more correct, than that of building triangles upon the sides of other triangles.

If the nature of the ground admits of this method of extension, a large tract of country may soon be covered with a net-work of triangles, the apex of each of which determines the position of some useful point, from which the details may afterwards be sketched. These general principles are applicable to all descriptions of surveying which are carried on with the aid of instruments.

PLOTTING THE ANGLES.

When the angles have been measured, it is necessary to consider whether they should be plotted in the field, or whether the distances of the various points should be calculated by simple trigonometry. The instrument used in the field to plot the angles is the common six-inch protractor, with which, even with a very fine pointed pencil, it is difficult to plot the observed angles nearer than one-third of a degree. If then any great accuracy is attempted, these principal distances should be calculated. For an ordinary military sketch, however, they may be plotted in the field; care should be taken that the

protractor is laid along the base line when the angles are measured with regard to the base, and that it is arranged according to the east and west lines when the "bearings" of any objects are taken with the compass from either end of the base. The difference between these two methods will be explained under the head of "compass" and "sextant."

THE SCALE

The purpose for which a sketch may be intended will mainly regulate the scale upon which it is constructed. When it is required to show every detail, such as the form and number of the houses, and the minute irregularities of ground, a large scale, such as 200 yards to an inch, or even 100 to the inch might be used. For ordinary military purposes a scale of six inches to a mile, or about 350 military paces to 1 inch would suffice, whilst if a long line of road of thirty or forty miles were required, a smaller scale might be used.

If several individuals should be required to survey or sketch portions of ground, which portions are to form one large sketch, it is essential that they should all work upon the same scale, which therefore should be previously agreed upon, and the measuring instruments compared.

When sketching, it will be necessary to remember the size of the scale, so that we may not waste time in putting down minute details, which could not

be visible on our sketch, nor omit to notice objects which might be of service.

It is essential that when the fair sketch is made from the rough one (which may be accomplished by pricking off), or when the rough sketch is inked in, the scale used should be actually drawn upon the sketch, and not merely an indication given of the proportional dimensions. An individual to whom the sketch may be given, can then measure any distance off the plan without difficulty. The direction of the north, south, east, and west, should also be shown on the sketch, and the magnetic as well as the true north, the method of finding which difference will be explained under the head of compass. The name of the sketcher should be inserted upon the sketch, the date when the sketch was taken, and the name of the locality sketched. All these details should be added to every sketch, before it is allowed to leave the possession of the constructors.

ARTICLES REQUISITE TO BE CARRIED.

Some instrument with which to take bearings, or angles, such as the compass or sextant. A sketching-case of leather, which should be fastened around the neck by a strap. A card-board, suited to fit upon the outside of the case. A few sheets of thin paper, upon which fine lines have been ruled in ink, parallel but at unequal distances, from one-third to one-fifth of an inch. A hard and soft pencil, a

protractor, upon the edge of which should be the scale which we purpose using, a pair of compasses, in case the protractor has not the required scale on its edge; a pen-knife, a piece of India-rubber, and a memorandum book. If the protractor, the pencil, and the India-rubber be tied to the sketching case, there is no chance of either being dropped. Instances so often occur of inexperienced, or thoughtless individuals, losing a considerable amount of time in consequence of having lost pencil, protractor, knife, or some useful aid, when far away from any place where these articles could be procured, that no precautions should be neglected to avoid such contingencies.

CHAPTER II.

THE PRISMATIC COMPASS.

By the aid of this instrument horizontal angles can be measured to within about one-third, or one half of a degree. The compass is usually held in the hands when the bearing of any object is being taken, but it can be placed upon a stand, by which means greater accuracy is obtained.

The compass is particularly useful for filling in the details of a survey, for sketching along a road, or river, or for making a sketch of any continuous line. By the *"bearing"* of any object, we mean the angle, which a line drawn from the object to the observer, makes with the magnetic north and south line, the bearings being counted from the north round to the right and up to 360°.

DESCRIPTION OF THE COMPASS.*

A circular brass box, about 2½in. in diameter, contains a graduated card, or non-attracting metal ring, under, or across which, a magnetic needle is fixed.

* See Sketch of Compass.

This card or ring is sometimes divided to one-third, but more commonly to half a degree. S is termed *the sight-vane,* down the centre of which a horsehair H is fixed. Below this sight-vane, outside the box, is a small spring which, when pressed, will check the movement of the card, which otherwise will move freely on its centre. The needle and card, are accurately balanced on an agate point, and should vibrate easily from side to side.

P is the prism, E the eye-hole, above which is a slit, through which the horsehair on the sight-vane can be seen, when the instrument is held horizontally up to the eye. At the lower part of the prism there is a small opening, which permits the figures on the card to be seen through the eye-hole, the 0 of the card being at the south, and the graduations from right to left to meet this arrangement. This opening is protected by a small shutter. A small lever which should be placed under the sight-vane throws the magnet off the agate point when the instrument is not required for use, the lever being pressed when the sight-vane is turned down. A mirror is sometimes attached to the sight-vane, and coloured glasses to the prism; they however considerably add to the expense of the instrument, without being of much practical use for ordinary purposes. The mirror might be used to take the bearing of the sun, or of a very elevated object, and the dark glasses would protect the eyes from being dazzled by any brilliant object.

HOW TO USE THE COMPASS.

When the compass is required for use, the sight-vane and the prism should be turned up, and the card allowed to play freely. The compass is then held horizontally, and so that the slit in the prism, the hair on the sight-vane, and the object, the bearing of which is required, should be in the same straight line. The card will continue to swing backward and forward during some time, when the compass is thus held, but will soon come to rest, even by itself. When the card is stationary, as it is graduated backwards, the number on it, which is opposite the hair on the sight-vane, and visible through the eye-hole of the prism, will be the magnetic bearing of the object.

The true bearing of any object can only be shown when the card comes to rest *by itself*, and therefore the observer must wait for this to occur: he may however check the swing of the card when it is about midway in its course, and thus diminish the extent of the vibrations, the card will then come to rest by itself. For example, if we saw through the eye-hole that the card stopped at 10°, and then moved round to 30°, we might press the spring when we found 20° under the hair of the sight-vane, and then gently releasing the card, allow the magnet to settle in the magnetic meridian.

When first using the compass, sometimes difficulty is experienced in seeing the numbers on the card through the eye-hole. This may be remedied by

raising the prism, unless it arises from the compass not being held horizontally. The card then either rests against the glass and is too near to the prism, or is too far off to suit the focus of the reflecting glass. Attention should be directed to this point, as the card cannot play freely in consequence of the friction, when it rests against the glass, and thus an incorrect bearing might be read. One or two trials should be made, and the bearings of different objects should be taken two or three times, in order to test the accuracy of the observations when the first attempt is made.

HOW TO PLACE THE BEARINGS ON PAPER, CALLED PLOTTING THE BEARINGS.

An observer who is taking angles or bearings, to any objects, is always supposed to be standing at the centre of a circle, the circumference of which is the horizon. All circles are divided into 360°, and it is usual to count these degrees from 0 round to the right, the quadrants being 90°, 180°, 270°, and 360°, or 0.

On the compass card, when seen in the prism, the 0 and 360° coincide with the north point, and therefore the degrees marked upon the card will, when read off, stand as follows—

North or 0°; from 0° to 90° will include the quadrant from north to east.

From 90° to 180° will include from east to south.

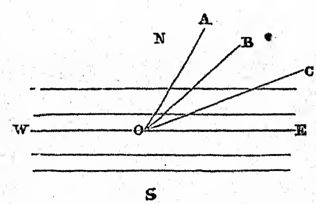
From 180° to 270° from south to west.

From 270° to 360° from west to north.

All the bearings with the compass being taken relatively, with the magnetic north and south, it becomes necessary when plotting these bearings to lay down some line or lines, which will represent the magnetic north and south, or the magnetic east and west. If we draw a series of lines to represent the magnetic east and west, then the magnetic north and south will of course be at right angles to these lines.

When dealing with these lines it is necessary to remember that as soon as we have determined to call them east and west, or west and east, we have then fixed the four points of the compass. Thus, if we place the west on our right, then the south will be represented by the upper part of the paper, and the north by the lower portion, or the converse.

Suppose W E to represent a series of parallel



lines, which are east and west, the east being represented by E, then the upper part of the paper will be the north, and the lower the south. If we speak of degrees instead of the points N.E. W.S., we should

have between O N and the direction of the line O E, from 0° to 90°.

Any bearings which may be observed between 0°, and 90°, must therefore be set on paper in the direction between N and E. Thus, suppose O were the position of an observer, this point being assumed where convenient upon the paper, then any bearings such as 20°, 30°, 60°, &c., up to 90°, must be set off in the direction of O A, O B, O C, &c.

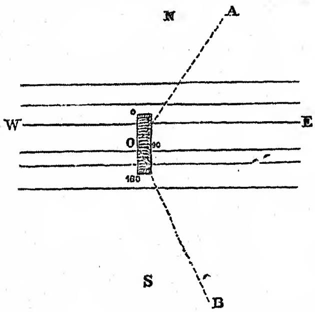
These bearings may be conveniently plotted, by means of the common six-inch ivory protractor, across which a number of equidistant parallel lines should be cut, so that the protractor may be laid at right angles to the lines W E, even if the point O does not coincide with any of them. This may be arranged if the lines W E are drawn parallel, but at *unequal* distances, for there will then be some line across the protractor, which will coincide with one of these parallel lines, even if the central protractor line should not agree.

We will now suppose that we have ruled a piece of paper with several parallel lines, which represent the west and east, and that we require to plot several bearings.

From that which has been already mentioned, it will be evident, that as all bearings between 0° and 90° lie between N and E, so all between 90° and 180° will lie between E and S. All between 180° and 270° between S and W. All between 270° and 360° between W and N; and all these bearings

must invariably be plotted from O, the position of the observer.

The protractor is laid down so that the centre rests upon O, and the bevelled edge, upon which the degrees are marked, is turned towards E. By means of the lines marked across the protractor, it can be arranged at right angles to the lines W E, and thus all bearings between 0° and 180° can be plotted from O, the observer's position, without moving the protractor.

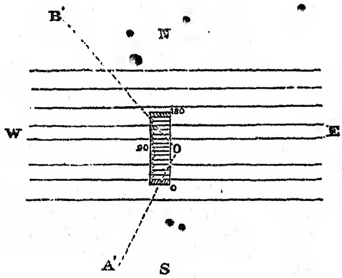


Thus, if we wished to set off a bearing of 40°, we should mark on the paper the 40° of the protractor, counting from N round to E, join this mark and O, and produce the line, which would consequently denote a bearing of 40°. If we required to set off 150° from O, we should arrange the protractor as before, mark the 150th degree, counting still from the direction N as our starting point, and this bearing would be represented by a line in the direction of O B.

If we obtain any bearings beyond 180°, it is evident that these must be plotted in the direction of W, or in the opposite semi-circle to that in which bearings less than 180° have been plotted.

These bearings are very easily set off by merely turning the protractor round, as shown in the follow-

ing figure, the bevelled edge being now to the west of the observer's position O.



Some protractors are numbered from 0 to 180, and then below are the corresponding figures from 180 to 360. With a protractor thus marked, it is merely necessary to set off the bearings, according to the divisions in the direction B', these degrees being taken from the protractor.

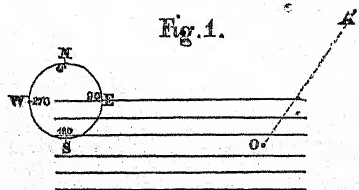
When the protractor merely reads to 180, then we should subtract 180° from all bearings which may be greater than 180, and then set off the remainder, according to the marks on the protractor. Thus, 200° would be 200—180=20°, to be set off from S round towards W. 300 would be 300—180=120°, to be set off in the same manner. This arrangement will be evident when it is remembered, that from N to E is 90°, from N to S 180°, from N round to W 270°, and so on.

It is sometimes found convenient, to work with the south at the upper portion of the paper; when this

is the case, the bevelled edge of the protractor will still be turned to the east, when we require to set off from 0 to 180°, without subtracting 180, but this edge will then be turned to the left hand.

To prevent any confusion as regards the direction, in which a particular bearing should be plotted, it may be useful, to construct a small circle in the corner of our paper, upon which the points of the compass, and the corresponding degrees are written. If then we remember that we are supposed to be standing at the centre of a circle when we take any bearings or angles, then we can at once observe in which direction these bearings should be laid down. The two following diagrams will aid to explain this.

Fig. 1.

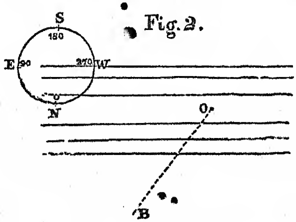


In fig. 1 the north is represented by the upper portion of the paper—the east by the right hand. The small circle shows the relative direction which different bearings would have.

Suppose from O, fig. 1, a bearing of 30° is required to be set off, then this bearing will be in the direc-

tion of O A′, as will be evident from the numbers on the small circle, N, E, S, W.

Fig. 2.



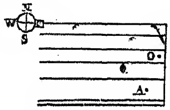
In fig. 2 the *south* is at the top of the paper, the west consequently at the right hand. The small circle S W N E, shows the direction of the various bearings, when S is at the upper part of the paper.

If from O a bearing of 30° were required to be plotted, then the line would be drawn from O in the direction of B.

Thus, if we suppose that the point of observation is the centre of a circle, represented in each case by the circle at the corner of the paper, we can at once decide in which directions the lines which represent the bearings should be drawn.

In consequence of the edge of the protractor projecting beyond the paper, it may sometimes be found impossible to mark off the degrees in the usual manner. Should this happen, we may mark off the opposite angle, and produce the line through

the point. Thus, suppose O a point on the sketching-case from which we required to set off



20°, we might mark the 200° at A, and produce the line A O in the direction required.

CHAPTER III.

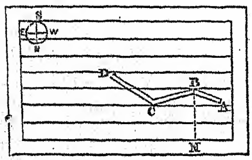
TO DETERMINE THE RELATIVE POSITION OF ONE OR MORE POINTS.

FIRST METHOD.

We will first suppose these points to be on a continued line such as a road, which, however, does not lie in a straight line. Having prepared the sketching-paper, by using a number of parallel lines, ruled as before described at page 10, we should take a bearing along the road, to some point to which the road is straight. As soon as we have taken this bearing, we can (if we have not previously examined the road) decide in which direction we purpose to work, and consequently at what part of the sketching-paper we should commence plotting. If we should find the first bearing about 90°, when the south was the upper part of the paper, then we should commence plotting, from the centre of the right hand side. If the north should happen to be at the upper part, then we should commence from the left, if the same bearing were obtained. An examination of the line of road is to be recommended, so that we may avoid that confusion and patchwork

sort of proceeding, which occurs when we have to recommence our work frequently, at different parts of the same piece of paper. The sketcher's own judgment must guide him in this matter. Having taken the first bearing, and plotted this, it is then necessary to pace, or measure, the distance from our own position, to that which we have observed. Thus we have the direction, and the distance, of this point, whose position is therefore determined.

From this second point, we should take a second bearing along the road to the next bend, plot the bearing, and pace the distance, which we should mark on our line. Thus, by taking bearings of every bend, and pacing from point to point, we determine the relative position of these, and hence the direction and length of the road, river, or line, along which we may be sketching.



Thus, B bears from A 120°; distance A B 100 paces. Set off A B 120°, and mark B distant 100 paces from A.

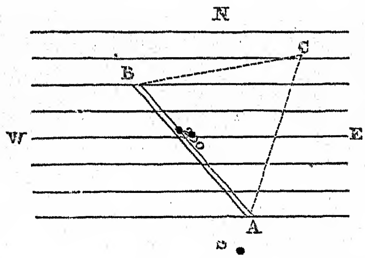
C bears 75° from B. Set off B C 75° from B N, and mark the distance B C found by pacing, take the bearing of D and so on.

SECOND METHOD.

The position of any point may be determined by means of a measured base, the bearing of which we know, and bearings to this point from both ends of the base.

Thus, suppose A B a line, the bearing of which was 330°, and length 200 paces, and C a distant point, the position of which was required.

From A the bearing of C should be taken and plotted, and also from B the bearing of C should be



observed and plotted; the intersection of A C and B C would determine the position of the point C.

In the same manner several other points on either side of the line A B might be determined.

It is not necessary that our measured base should lie in the same straight line, provided that we know the relative position of the two points from which we take bearings to the third point. It is well to remember this when sketching along a road, an operation which will shortly be described.

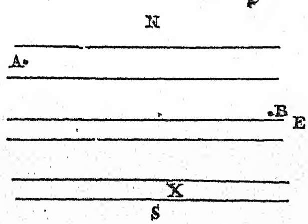
INTERPOLATION.

Interpolation is the term, applied to the process of determining our own position upon a sketch, by the aid of two other known positions. The principle of

this process is, that if there be two points, A and B, and that if A is south of B, then B is north of A; or if A be west of B, then B is east of A.

In practice it would rarely happen, that we should obtain two known points, either directly to our north and east, or to our south and west; still the principle is the same, viz., that from one of the known points we set off the opposite bearing to that which we have observed from our position, and we then know that our position must be somewhere in that line. If then we set off from some other known point, the opposite bearing to that which we have observed, the intersection of these two lines, will determine the position of the point, from which we are observing.

This method is particularly useful, both in checking portions of a survey, as well as in connecting one part with another, or in determining the position of



any required point. Suppose A, and B, two points previously fixed upon our sketch, and that we observe from some unknown point X, the bearing of A, which we find 340°; the opposite bearing to 340° is 160°. If, then, from the known point A we set off 160°, the unknown point X would lie in this line.

Upon taking the bearing of B we find it 40°, the

opposite bearing to which is 220°, which is therefore set off from the known point B, in the direction of X. The position of the point X will be determined by the intersection of the bearing 160° from A, and 220° from B.

The only difficulty which the beginner is likely to encounter in this method is to tell which is the opposite bearing to that observed. This question he can at once answer by supposing that he is standing at the centre of a circle, and that the bearing which he has observed is produced through the centre, until it cuts the circumference behind him; the line behind him, will thus represent the direction of the opposite bearing. In the preceding examples the bearing 340° was 20° short of 360°. The opposite to 360° is 180°, and 20° short of 180° is 160°—the opposite bearing therefore to 340°. In the second instance, the bearing of B was 40° from, or on from the north; the opposite bearing was therefore 40° from, or on from the south, and as the south is 180°, therefore the opposite to 40° would be 180°+40°= 220°. In like manner the opposite bearings to 10°, 30°, 60°, 80°, 110°, &c., would be 190°, 210°, 240°, 260°, 290°, &c.

The application of this method of determining the position of a point, must in a great measure be left to the judgment of the sketcher, but there is scarcely any case in which it may not be applied with great advantage, and may save the individual employing it from errors, as well as from a considerable amount of unnecessary pacing.

Where possible, three points should be chosen from which to interpolate, as a position fixed by the intersection of three lines is more likely to be correct, than one which is obtained, by the intersection of two only. Also two or more points should be chosen, so that the intersection of the lines set off from these points, may make an angle of about 60°. Acute intersections should be avoided when interpolating.

SKETCHING A ROAD.

One of the most common operations required from a military surveyor is to sketch a road. The work in itself is particularly simple, and requires merely the commonest knowledge of sketching; still to produce a good sketch of a road, in a very short time, requires practice and attention.

To sketch along a line of road we select some point from which to start, from this point we take bearings to the first bend in the road, and pace the distance, and so continue taking bearings, and pacing, to each bend in the road. (Page 24).

This is the principal portion of the work; but it is also necessary to place upon paper every object, such as houses, hedges, walls, water courses, cross roads, or other objects, which may be situated upon either side of the road, or within a distance of two or three hundred yards.

The position of the objects at the side of the road may be found by pacing only, whilst the position of those situated at a distance, can be determined by

means of two bearings taken at different parts of the road, the distance between the two stations from which the bearings are taken, being of course determined.

It should be particularly pointed out that when a sketch of a road is called for, it is necessary not only to sketch the road itself, but every object which can be seen clearly from the road, and which might affect, in a military point of view, the movements of troops.

Whilst it is essential that the sketch be made with considerable rapidity, and that minute accuracy should not be aimed at, when an imperfect Instrument like the compass is used, and when pacing is our only means of determining distances, still it is necessary that all those details which might affect the march, or movement of troops, should never be omitted.

A small running stream, a pond of drinkable water, a patch of wood, a few detached houses, &c., would be very important items if we purposed sending troops along a road, and to omit any of these would show either neglect, or want of observation, on the part of the individual, who having time, had yet omitted to show them in his sketch.

The sketcher being provided with the articles mentioned at page 10, may start from any point in the road, take a bearing and plot it as already explained, pace the distance, or if mounted, count the paces or strides of a horse. Previous to starting, however, bearings should be taken to any remarkable objects

around, or these may be sketched in by eye. Another bearing is then taken and so on.

When the field-sketch is finished, it may be clearly inked in, the various conventional signs being used to denote different objects. It should then be finished as mentioned at page 10. If the sketching-paper be crumpled and dirty, the sketch can soon be pricked off on fresh paper.

TO MAKE A SKETCH WITH THE AID OF THE COMPASS.

If required to make a sketch of a portion of country of about six square miles in extent, we should first select the most commanding point of view from which to examine the general features, and we should thus become acquainted in a measure with the locality upon which we should have to work. We could select those prominent objects which appeared the most likely to be of service to us in our sketching, and also we might note whether there was not some suitable position for a base line.

If possible, a level piece of ground of about 600 or 700 paces, or more, should be selected, upon which to pace a base line, and we should so arrange that the terminations of this base, should consist of remarkable objects, such as steeples, tall trees, sign posts, houses, gates, or any other objects which can be seen from a distance. Having paced this base line two or three times, so as to ensure a tolerably accurate measurement, we should take the bearing, from

both ends, and thus obtain a check upon a single bearing. The accuracy of a survey, depends upon the correctness of the measured base, and upon the angles taken from either end, so that a little time and attention devoted to this first step, will usually save time and trouble in the details, and will also ensure accuracy. There are so many sources of error when pacing and taking bearings, over which the sketcher has no control, that no chance of error should be incurred where it can possibly be avoided. Thus a considerable amount of attention should be devoted to the measurement, and bearing, of the base line.

Having selected as many prominent objects as possible, in various parts of the country which we purpose to sketch, we should then take and plot the bearings of these, from both ends of the base line. The intersection of these bearings will determine the position of the objects. If we have the means at our disposal, far greater accuracy is attained when we can rest the compass on any fixed body. We can also take several bearings more quickly if we turn the compass-vane slowly round, so that the sight-vane may be directed upon the various objects in succession. Great caution must be taken that no object is used for a rest, about which there is any iron; thus, although gates, or railings, may sometimes be used for rests, still if there be any iron railing, or hinges, within a yard or so of the compass, very great errors in the bearings would result. A small mound of earth may usually be found, or may

readily be made, and the bearings can be taken whilst the sketcher is lying down. If no such advantages can be obtained, then the bearings should be taken with the greatest care in the usual manner, and all acute intersections guarded against.

From either end of the base, or from any of the points which have been determined, we could next proceed to take the bearings and pace, to some main road, river, hedge, or other boundary, and by the method before explained, we could sketch the road which was nearest the boundary of the country which we proposed to survey. Those points, the position of which we had determined, could now be made use of to determine by interpolation, our position, and thus to check the pacings and bearings at different parts of the sketch. It is advisable first to sketch the extreme boundary lines, and then to work in the interior details. It is very easy to discover whether the sketch is proceeding with tolerable accuracy, by noting how the junctions of various roads, footpaths, &c., agree, when plotted with the measured distances. If, for instance, we were to measure round a circle, and upon plotting our work were to find that from a point A, round to A, was 2,000 paces, but that when we plotted the line along which we had paced, we found that 2,000 paces would not reach A by 100 paces, then we should know that some of our paces were too long, or that some other error had been made. Thus, if we start from any point, and sketch round to this point, we can ascertain whether or not we have paced with tolerable accuracy.

It would of course depend upon the amount of correctness required in a sketch, whether, if an error were discovered, we should repace the ground, or merely divide the errors over the whole sketch. When, however, due precaution is taken, both with the measured base, the general pacing, and the bearings, and when a constant check is kept up by interpolation, no errors greater than about ten paces per 1,000 would occur.

Having made an outline of the boundary of our country, we should next sketch the roads, bye-ways, footpaths, water-courses, walls, and hedges, taking care to mark the woods or plantations, the houses, barns, farm buildings, and all the other notable objects. In this portion of the work, the amount of detail required, and the time at our disposal, would determine the amount of accuracy.

In a military point of view it would scarcely be necessary to place every hedge, and every bend in this hedge in its proper position, nor would it signify much whether the hedge were 40 paces one way or the other, but it might be a matter of the greatest importance, that we pointed out, that an apparently insignificant water-course was impassable for artillery on account of its steep banks, or that a thick hedge and bank would check cavalry, &c., &c.

When the sketcher has unlimited time at his disposal he should notice everything on his sketch, but as this rarely happens on service, each individual should remember to what objects his attention should be directed, so that when his time is limited,

D

he may avoid wasting it in attending to paltry details, whilst matters which might influence a battle, are overlooked from want of time or opportunity. It is in matters of this description that considerable judgment is required, and it is here that individuals would have the means of distinguishing themselves. To make a sketch of a country is in itself a very simple matter; but when the time is limited, and when probably an enemy is near, some thought and skill is required to transfer upon paper just those military features which a General about to move troops in a country, would require to know. It is not every person who may be gifted with either great skill or judgment, but each individual is able to cultivate those natural talents which he may possess, and thus to be the better able to make use of these, when he may be suddenly called upon.

The sketch having been made in the field may either be inked in, or pricked off, on a fair piece of paper, across which one or two east and west lines have been drawn, so as to serve as a guide to the placing on of the various sheets of sketching paper. The sketch should then be finished as before recommended. (See page 10).

The hill-sketching can be performed either at the same time as the road-sketching, or afterwards, but this subject will be fully treated of at a future page.

SUMMARY OF THE COMPASS.

With the prismatic compass we can take the "*bearings*" of different objects.

By this means we can determine the relative position of a point by three methods.

1st. Take the bearing of the object, and pace towards it; a method employed in road traversing.

2nd. Measure a base line, and take the bearings of the object from both ends of the base; a method useful in fixing the positions of objects on either side of a base line, or road.

3rd. By interpolation; that is, taking the bearings of two known objects, and setting off from these points, the opposite bearings to those observed; a method useful either to check the work in a sketch, or merely to find one's own position.

The compass is very useful for surveying along a road or any continued line, or in any position in which the field of view is extremely limited, and the angles which are taken with it are necessarily horizontal angles. Its disadvantages are, that it is difficult to use in windy weather, and is influenced by iron; thus in some localities, it cannot be used with accuracy.

TO FIND THE VARIATION OF THE COMPASS.

The most simple method of obtaining the variation of the compass is to take the bearing of the sun's centre as it crosses the meridian. With the aid of the mirror on the sight-vane, and the coloured glasses, the bearing of the sun can be readily obtained. Care should be taken that the compass is truly horizontal when the bearing is noted. To obtain the greatest accuracy, it is better to rest the instrument upon some level surface.

The instant that the sun crosses the meridian may be found, if we know the local time of the place of observation, and add to, or subtract from the local time, the difference between sun time and mean time.

Thus, if on January 31st, we made our observation, we should find the sun about 13½ minutes after the local time, consequently at 13½ minutes after twelve o'clock the sun's centre would be upon the meridian, and the difference between the then bearing of the sun, and 180°, would give the variation.

The difference between the sun time and clock time, is given for each day, on page 1 of the Nautical Almanac. When the heading is "Equation of time to be added to apparent time," the clock is before the sun, when "to be subtracted," after the sun.

The method of finding the sun time is given under the head of Longitude, and the time thus found, would enable us to find the variation of the compass by means of the sun.

The bearing of the pole star may also be taken, and as this star will be exactly north of an observer twice during every twenty-four hours, the time may be selected, when it is on the meridian, to observe with the aid of the reflecting mirror, its bearing.

The pole star is on the meridian, when a vertical plane passes through it, and the third star from the tail of the Great Bear, either above or below the pole. Thus, during the twenty-four hours two opportunities will be presented of finding the pole star on the meridian. When a horizontal line passes through the same two stars, then the pole star will be 1° 27′ from the pole, and *east* or *west* of the true north, according as the other star is *west* or *east* of the pole star. Thus, by adding or subtracting 1° 27′ from the observed bearing, the true variation may be found. This method is in practice more difficult than the former one, in consequence of the light required to see the compass-bearings preventing our seeing the star; a distant object may, however, be chosen exactly beneath the pole star, and selected by means of a pendulum, and the bearing of this object taken.

Several other methods may be adopted, one of which is very suitable for tropical regions, where the sun descends nearly vertically beneath the

horizon, that is to take the bearing of the sun when it is a semi-diameter above the horizon, then the true bearing of the same being found by spherical trigonometry, the compass bearing can be compared therewith, and the variation determined; this is suitable when we have the sea for our horizon and are at the sea-level.

The variation of the compass at the present time at Greenwich is about $21\frac{1}{2}°$ west.

CHAPTER IV.

THE POCKET SEXTANT.

The pocket sextant is one of a numerous class of reflecting instruments, and possesses the advantages of being portable, of requiring no other support than the hand, of being easily adjusted, and of requiring no adjustment other than the first. This instrument is more correct than the compass, as we can read an angle to within 1′ by means of the vernier on the graduated arc, and being a reflecting instrument it is not influenced by local attraction, or magnetic variation. It can also be used on horseback, and in all weather.

When not required for use, the sextant is packed in a small box, in which manner it can be conveniently carried either in the pocket, or in a small leather case slung over the shoulder.

When required for use, the case should be unscrewed, and the small slide at the under part of the sextant pushed back, the dark glasses can then be pressed down through the opening, by means of a pair of levers at the side of the in-

strument. The lid should then be reversed and screwed on to the lower part of the sextant, which will then appear as shown in the sketch, the telescope having been withdrawn, if it had been previously placed within the instrument.

The various parts of the sextant are named as follows: *—I, the index-mirror: H, the horizon-glass, the upper half of which is silvered, and therefore reflects objects; B, the index-arm; S, a screw, by means of which the index-arm is moved; V, the vernier, which enables minutes to be read; A, the adjusting-key; X and Y, the key-holes for adjusting the horizon-glass; a key for holding the support of the telescope is sometimes added near the adjusting-key. E, the eye-hole; G, the glasses for intercepting the sun's rays; C, the graduated arc.

Before taking an angle with the sextant, we should examine the instrument to see whether it is in adjustment.

The most simple method to determine this, is to select some *distant* object, such as a chimney, house, or flag-staff, and then look at this object through the eye-hole and horizon-glass. Then turn the index-arm, by means of the large mill-headed screw, until the reflected image of the selected object coincides in the horizon-glass with the object seen direct. Having effected this, the vernier should then be examined, to note whether the zero point of the vernier marked ↓ coincides with the 0 of the graduated scale. If this coincidence occurs, and

* See plate of Sextant.

the observed object be distant *fully half a mile,* then the instrument is in adjustment, and is ready for use, but if the two zero points do not agree, the index-arm is moved until they do, and the key is then placed in one of the key-holes, and the reflected image of the distant object is made to coincide with the object seen direct through the lower part of the horizon-glass. The key is inserted in the key-hole on the *top* of the instrument, when it is required to move the image up or down, and in the key-hole at the *side,* when the image is required to be moved to the right or left.

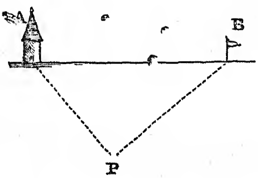
These are the only adjustments that the sextant requires, and we should be careful not to attempt to make these, until we are certain that they are required, and that the object which we observe is at the distance of fully half a mile. Many good instruments become damaged in consequence of individuals being very anxious to adjust, before they really are aware how to perform the operations, or whether the process is really necessary.

Having placed the sextant in adjustment, we may then proceed to take angles with it. The process is as follows :—

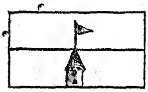
TAKING ANGLES.

Suppose A and B two objects, and P our position; the angle which we can measure with the sextant is the angle A P B.

The sextant is held so that the plane of the top of the instrument is parallel to a line joining A and B.



The sight is directed through the eye-hole and the lower part of the horizon-glass to the left hand object A. The index-arm is then turned slowly by means of the mill-headed screw, until the re-



flection of the object B coincides with the object A. This coincidence will then appear in the horizon-glass in the manner here represented. The angle between the two objects, A and B, that is, A P B, can be read off the graduated arc.

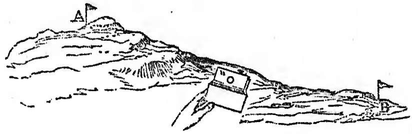
If we should be required to direct the sextant on the right hand object B, and to bring the left hand object into coincidence, we should merely have to invert the sextant, and proceed as before. Thus, if we direct on the left hand object, and bring the right hand object round, we hold the sextant with the screws uppermost. If we direct on the right

hand object, and bring the left hand round, we must hold the instrument so that the screws are below.

If it is required to measure vertical angles, such as the altitude of buildings, masts, mountains, &c., the instrument is held with all the screws to the left. The sight is then directed on the lower object, and the reflected image of the upper object is made to coincide with the lower one seen directly. The angle measured is that made by the intersection of two lines, drawn from the eye of the observer, one to each object, these being the angles invariably measured by the sextant.

Upon first attempting to practice taking angles with the sextant, the observer may probably find some difficulty when he endeavours to make the objects coincide in the horizon-glass. This difficulty usually arises in consequence of turning the large screw with too much rapidity. By this means the object is either passed over, or escapes being seen as it passes by reflection across the mirror; a few *small* angles should first be attempted, and afterwards larger angles. Sometimes the two objects cannot be seen in the horizon-glass, because the sextant is not held so that the plane of the instrument, is parallel to a plane, in which are the two objects. Thus, if A and B, were two objects, the sextant should be held as shown on p. 44, so that the top slopes from the one to the other. The instrument should be slightly moved, so that, with a sort of swaying motion, different objects are brought by

reflection upon the horizon-glass. Care must also be taken that the hand or arm does not come between the index-mirror, and the object required to be seen by reflection.



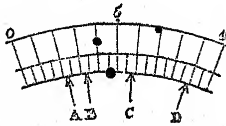
All these disturbing causes, although trivial, frequently retard the tyro, and cause him, if unaided, to imagine that there are difficulties where there should really be none.

TO READ THE ANGLES BY MEANS OF THE VERNIER.

The principles upon which verniers are constructed are very simple, and a few examples upon the reading of the angles will now be given.

The graduated arc of the pocket-sextant is usually divided into degrees and half degrees. The half degrees being marked by a shorter line, as shown on p. 45, where an arc of 10° is delineated, and is divided into half degrees. To read an angle, it is first necessary to observe where the arrow-head of the vernier rests upon the graduated scale, we can thus find how many degrees the angle which we

have observed may contain. Thus, if the arrow-head of the vernier were at A, we should have 2°



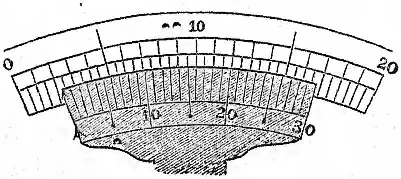
and some minutes. If at B, 3° and some minutes. If, however, the arrow-head of the vernier lies beyond one of the short divisions, as at C, the angle will then be 5½° and some odd minutes, at D it would be 8½° and some odd minutes; the half of the degree being carefully noted, before we attempt to read the minutes from the vernier. A little attention to this point will save much confusion when attempting to read angles.

Having noted how many degrees are indicated, and whether there be also a half degree, the lines on the vernier are then examined, when some line will be found which is in the same straight line, as one on the graduated arc. The various vernier lines will be seen to approach nearer and nearer to the lines on the arc, until at length one line exactly coincides. The number of this line, *read from the vernier*, will give the number of minutes in the angle, up to 30′, and as the degrees have been previously determined, we then have the whole angle on the arc to within 1′. If the 10th division on the vernier coincided with a division on the arc, then the angle would be so many degrees, *and* 10′; or so many degrees and

40′, just as the arrow-head happened to fall short of, or to be beyond, the half degree. If it should be beyond the half degree, then this half degree=30′ should be added to the minutes found on the vernier: two examples are here given.

In the two following figures the vernier is shown dark; the graduated arc on which are the degrees and half degrees, is shown white.

FIG. 1.



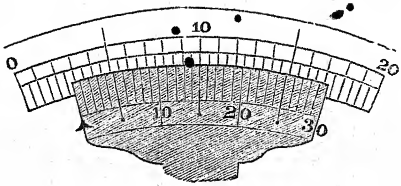
In the above figure, $14\frac{1}{2}°$ of the graduated arc are taken to form the vernier, which is divided into thirty parts.

To read the angle shown in fig. 1, we note where the zero of the vernier rests, and we find that the second long division is passed, but not the third short one; thus we have 2°. We next examine the vernier, and run the eye along the lines until we find a line on the vernier coinciding with one on the arc. The 15th or 16th division appears thus to coincide; consequently the angle shown in fig. 1, is 2° 15′, or 2° 16′, according as the 15th or 16th line is found to be that, which coincides the more nearly with a line on the arc.

In fig. 2, the zero of the vernier has passed the 2°,

and also the short division between the 2nd and 3rd degree. We have then 2° 30′, plus the minutes,

FIG. 2.



which we may find on the vernier. On examining the vernier, the 15th division appears to coincide with a line on the arc; this 15′ added to 30′ gives 45′ for the total minutes. Thus 2° 45′ is the angle shown by the vernier at fig. 2.

THE PRINCIPLE OF THE VERNIER.

To form a vernier it is necessary to take a certain number of parts (N) from the scale, and divide the length into (N—1) or (N+1) parts. So that if V represent a division on the vernier, and L a division on the limb, then—

$$(N-1)\,L = N\,V.$$

$$\text{Hence } L - V = \frac{1}{N}\,L.$$

The vernier on the pocket sextant is constructed by taking 29 half degrees, and dividing this length into 30 parts. Thus, the difference between the length of a *vernier* division, and a division on the limb is

$$\tfrac{1}{29} - \tfrac{1}{30} \text{ of } 14^\circ\tfrac{1}{2}.$$

$$\tfrac{1}{29} - \tfrac{1}{30} = \tfrac{1}{870} \text{ of } 14^\circ\tfrac{1}{2}.$$

Therefore $=1$ minute, as $14^\circ\tfrac{1}{2} = 870'$.

The method of adjusting the sextant having now been described, and also how to take and read the various angles, it is merely necessary to point out how the observed angles are to be plotted, before a few remarks are made upon the practical use of the instrument in the field.

It is very necessary that the bearing of the base line should always be taken with the compass, and this base plotted in its proper direction. After this, the angles to the various prominent or remarkable objects in the surrounding country may be taken with the sextant.

The sextant is directed on one end of the base line, and the various objects are made to coincide with that end, the observer taking care to stand at the other end. The protractor should be laid so that its centre coincides with the point *upon which the observer is standing*, and the edge of the protractor should lie along the base line. The degrees and minutes of the angles are then counted from the opposite end of the base as a zero, and each line is drawn to the proper direction.

For this work a fine-pointed hard pencil should be used, and care taken to avoid a confusion of lines or dots, over the paper. It is advisable that a memorandum should be made, by which we may know to what object each line refers. Thus, our method of proceeding should be something like the following:—

Suppose Fig. 1 to be a portion of country in which are several prominent points, such as C, D, E, F, G, H, which will serve for stations. Having selected

A B for our base line, we measure this, and from A take the various angles H A B, G A B, F A B, &c.

Fig. 2 represents the sketching-case, on which we have plotted the base A B, the direction of which is assumed to be as represented. Directing the sextant upon B, we bring the church H to coincide with B, and with the protractor's centre at A, and lying along A B, lay off the angle H A B, draw the line H A, and write, in small letters, "church;" then take the next angle, and, having drawn the line, write "tree," and so on. We should thus know to what each line refers.

Having taken and plotted all the angles from A, we may then proceed to B, and direct the sextant on A, and take the angle to the gate or windmill. We shall, when at B, find the advantage of having written against the lines to what they refer; for from this station the relative position of many of the objects may have changed: for instance, C, the left-hand object seen from A, would not be the left-hand object seen from B.

When we plot the various angles taken at B, we need not draw the lines from B to represent these angles, but we have merely to mark on the line drawn from A, where the intersection would have occurred; and thus we determine the position of each object in succession. When we take the angle to the gate, we should merely have to note where the line drawn from B (at the angle observed) cut the line D A, and at this intersection a mark being made, would serve to determine the position of the

gate. A confused crossing of lines is thus avoided, and a habit of clearness at once adopted. The lines A C, A D, A E, have thus the intersections marked upon them, and these intersections determine the position of the points, C, D, and E.

In consequence of the construction of the sextant, the instrument will only measure angles of about, or less than, 110° or 115°. If it be required to measure a larger angle, we can easily select some point midway between the extreme points, and measure first the one portion and then the other, the addition of the two giving the whole angle. By this means even road-traversing can be accomplished, although with greater chance of error than with the compass.

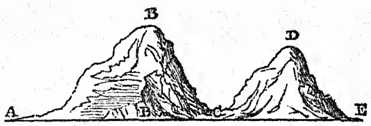
THE PRACTICAL USE OF THE SEXTANT IN SKETCHING.

The sextant is particularly useful for determining the position of various objects from both ends of a measured base, and being capable of giving angles with considerable accuracy is, for anything like a regular survey, much preferable to the compass. It can be made use of to determine the direction of woods, rivers, walls, or hedges, as we can take the angle which a bend in a wood may happen to make with its original position, and so proceed, plotting each angle as though our station were one end of a base, and then pacing the distance to the next bend. As before mentioned, this method is not so conve-

nient for road-sketching as is the method of taking the bearings with the compass, but in case we happened to have the sextant only, still a survey could be accomplished.

Having fixed the relative position of a number of objects, from either end of the base, we may then make use of any two of these, as the means of taking angles to, and therefore determining the position of any other objects, for these would serve as the direction and termination of a fresh base. We might thus fix the position of so many points, that simply by eye we could sketch in the details which might connect these points.

One of the principal objections against the pocket-sextant is, that in a hilly country the observed angles would not probably be horizontal angles; and thus, if we measured round the horizon from point to point, up and down, the sum of our angles would amount to more than 360°. This will be easily understood from the following figure:—



Suppose B D, the summit of two hills. If we measured with the sextant the angular distances between A and B, B and C, C and D, D and E, and then the true horizontal angular distance A E, we

should find the sum of the various distances A B, B C, &c., much greater than the angular distance between A and E. If, then, there were hills all round us, and we measured from the summit to the base of these, we might obtain 370° in our round of angles, whereas 360° ought to be the maximum.

This error in the instrument may be considerably diminished, if not entirely obviated, if we take some object exactly beneath the elevated point, such as B′, which point can readily be found by the aid of a piece of string and a weight, and measure the angular distance A B′ and B′ C, &c., B′ being as near as possible in the same horizontal plane as A and C. The greatest errors due to this difference of level would be when the horizontal angular distance between the two points was small, and the difference in altitude was great.

There would be no effect produced when the angular distance was 90°, although the objects were in different horizontal planes. If the two points happened to be both above the plane of the observer, then the angular distance measured with the sextant would be less than the horizontal angular distance due to the arc between the two objects. As before mentioned, this difficulty can be overcome by selecting two points below those which may be elevated above the plane of the observer, and then measuring the angular distance between the two. Or a point may be selected about 90° from one of the objects, then measure the angular distances from the selected point, first to one and then to the other object. The

difference between these two angles will be nearly the horizontal angular distance between the two objects.

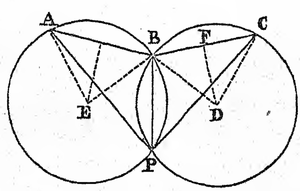
A little arrangement on the part of the observer will do away in a great measure with this source of error; for points upon the same level as the observer may easily be selected, or such angles avoided as might lead to untrue angular distances being taken. In an average country, however, the amount of error due to this cause will be very slight, and therefore too much importance must not be attached to it, especially when we plot the observed angles in the field, and with the common protractor.

The sextant and compass should be used together; the first to fix the position of some of the principal points, the latter to fill in the details.

CHAPTER V.

PRACTICAL PROBLEMS CONNECTED WITH THE POCKET SEXTANT.

A METHOD called "Interpolation" has been mentioned, by means of which we could determine our position on a sketch, supposing that we could take the bearings of two known points. With the sextant we can find our own position, provided that we know the relative positions of three other points. The method is as follows :—



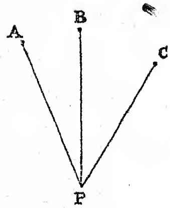
Suppose A B C, three known points, (selected for convenience npon the same side of P, an unknown point). It is required to find the relative position of P.

From P measure with the sextant the angles A P B, B P C. Double the angle A P B, and take this doubled angle from 180°. Halve the remainder and set off from A and B, angles each equal to this half remainder, that, is B A E, A B E, then A E=E B. With E as a centre, and radius A E, describe the circle A P B. Then the point P will be in the circumference of the circle A P B. In like manner double the angle B P C, and proceed as in the previous case, the point P will be in the circumference of the circle B P C. Being in the circumference of the two circles, the point P will therefore be at the intersection of the two. This problem depends upon the fact, that upon the same base the angle at the centre of a circle is double the angle at the circumference.

Suppose the angle A P B to have been 40°, B P C 30°, the double of A P B would be 80°, then 180°—80°=100°. Divide 100° by 2, and we should have to set off 50° from A and B, the three angles of the triangle E A B would be 50°, 50°, and 80°, A E B being 80° or double A P B. In like manner, 2 B P C =60°, and 180°—60°=120°, half 120°=60°, from B and C set off 60° degrees and the triangle B D C would be equiangular, each of the angles therefore 60°, and the angle B D C consequently double the observed angle B P C. With E and D as centres, and radii E B and D B, the two circles are described, whose intersection determines the position P of the observer.

When we are in the field, instead of constructing

this figure, we may make use of the following method to find our position. Draw upon a piece of tracing paper any line A P. From the point P set off the angle A P B, equal to the angle observed between A and B the two known stations. Also from P set off B P C equal to the second observed angle. Then lay the tracing paper upon the sketch, and turn it about until the three lines P A, P B, P C, pass through the three points A, B, and C, we can then prick off the point P on to our sketch, and thus determine our position.



The distances or heights of any objects, can be readily found by means of the sextant, either by construction, as shown already, or by measuring the base, taking angles from both ends, and working out the plane triangle by trigonometry. To the practical man time is a great object, and that method should be adopted to arrive at results, and which is the more correct, and occupies the shortest time. There are now published several compact pocket editions of tables of logarithms,* and of sines, tangents, &c., to five places of decimals. These tables are invaluable to the practical surveyor, whose baggage should be as little encumbered with books as possible. Thus, by means of a table of logarithms and the sextant, the heights of mountains, distance of ships, batteries, forts, &c., could be determined in a very few minutes.

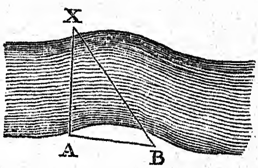
* Walton and Maberly's, price 1s. 6d., and others.

One or two examples may here be given for the aid of those who may not have practised trigonometry for some time.

The problems are particularly simple, and intentionally so; for the object should be to so prepare ourselves that we should be ready at a moment's notice to carry out practically that with which we may be acquainted theoretically. If, however, we deal principally with intricate problems, which rarely occur in practice, it not unfrequently happens that we cannot at the right time, and without previous preparation, at once readily perform some simple useful work. The following cases, therefore, should not be beyond the capacity of any military sketcher, and should be practiced in the field, so that they are completely understood; for explaining, or working out on paper, is a very different matter from actually performing the operation.

Prob. I. Suppose A X, the distance across a river, is required to be known.

Measure any convenient distance—A B—along the bank. From A direct the sextant upon some clearly-defined object, X, and measure the angle X A B. From B measure the angle X B A.



Suppose A B = 100 yards, and X A B = 85°, A B X = 40°. Then the angle A X B = 55°. Because the three angles of a triangle = 180°.

The sines of the angles of any triangle are proportionate to the opposite sides. Thus:—

The sine of A X B : A B : : sine of X B A : A X.

Then $A\ X = \dfrac{A\ B \text{ sine } X\ B\ A.}{\text{Sine } A\ X\ B.}$

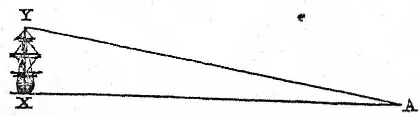
And using our table of Logarithms, we have—

$$\begin{array}{rr} \text{Log. A B, } i.\ e.\ 100 = & 2\cdot00000 \\ \text{Log. sine X B A, } i.\ e.\text{, of } 40^\circ = & 9\cdot80806 \\ \hline & 11\cdot80806 \\ \text{Log. sine A X B } 55^\circ = & 9\cdot91336 \\ \hline & 1\cdot89470 \end{array}$$

Number corresponding is 78·47 yards = A X.

If A happened to be a battery and X a ship, the distance A X could of course be found by the same means.

Prob. II. Suppose X a ship, the height (X Y) of



whose mast is known, and A a battery. It is required to find the distance A X, by means of the sextant.

Supposing the ship to be upright, we should here have A X Y a right angle. The angle Y A X could be measured with the sextant by making X and Y coincide in the horizon-glass. In the right-angled triangle Y A X $A\ X = \dfrac{X\ Y}{\text{Tan. } Y\ A\ X}$

Suppose X Y to be known, and to be 150 feet, and

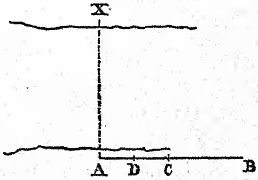
Y A X to be 3°, then the distance A X, would be 2862 feet.

All such problems may be solved by means of plain trigonometry, or the results may be reached by construction. If rather a large scale be used, and care taken with the plotting, a very close approximation may be made by this latter method, which requires the very smallest amount of theoretical knowledge.

A right angle may be laid off on the ground with the sextant by setting the index to 90°, and directing the sight upon one object (say a staff), and signalling to a man with another; so that he may plant the second staff in the ground when its reflected image coincides with the first staff seen direct, through the horizon-glass. Then, if our own position be marked, the lines to each object will form a right angle at our own position.

Having thus set off a right angle, we can readily obtain the distance of objects by means of what is called a "scale of tangents," the principle of which is as follows :—

Suppose A and X two objects, the distance between which is required, and that we have made X A B a right angle. If the angles A X B and A B X were equal, then the distances A B and A X would be equal. We



could, by selecting 45°, make these two angles equal,

by moving along A B until A and X coincided in the horizon-glass of the sextant, when the index was set at 45°. Then if we measured A B, we should know the distance A X, because the two sides would be equal.

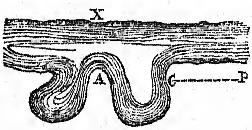
It might not be convenient to take so long a distance as A B, and thus the two angles A X B, A B X, instead of being equal, must bear some proportion to each other. It is found that if along the line A B, we selected some other point, such as C, so that the angle A C X was 63° 26′, then the side A X would be double the distance A C. Also, if we selected some other point, such as D, so that the angle A D X was 71° 34′, then A X would be three times the length of A D. By this means a table has been formed, so that either the height or the distance of any object may be determined without the aid of logarithms.

It is evident that if to obtain the distance A X, we have to multiply A D by three, so, if we knew A X, we might obtain A D by dividing A X by three, and as the angle X A D = 90°, and A D X = 71° 34′, therefore A X D = 18° 26′. Thus, for an angle of 18° 26′, we should have to divide the measured base by three, whilst for 71° 34′, we should have to multiply it by three. The following table shows the angles that may be used, and the number corresponding to the angles:—

MULTIPLIER.	ANGLE.	ANGLE.	DIVISOR.
1	45°	45°	1
2	63° 26′	26° 34′	2
3	71° 34′	18° 26′	3
4	75° 58′	14° 2′	4
5	78° 41′	11° 19′	5
6	80° 32′	9° 28′	6
8	82° 52′	7° 8′	8
10	84° 17′	5° 43′	10

Sometimes the nature of the ground might not admit of our measuring up to the point from which we had set off 90°; when this is the case we may proceed as follows :—

Suppose A X, the distance across a river is required to be known, but that a base cannot be measured except at C B.



From A set off 90°, X A C in the direction C B. By trial, select any point C, so that the angle X C A may be 45°, 26° 34′, 18° 26′, or any of the other *divisor* angles, but the nearer 45° the better. Then move along the line C B, until B a point is found where another angle in the divisor table may be used.

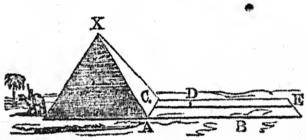
Suppose X C A to be 26° 34′, and X B A 14° 2′; the difference between the numbers corresponding to these two angles, that is the difference between

2 and 4, namely, 2 is used to divide the distance between C and B, which we can measure. Then the distance so divided is equal to A X, the distance across the river. Thus, if C B were 200 yards, then A X would be 100 yards.

The distance between A and C could also immediately be found, for since A C X=26° 34′, then A X multiplied by 2 would equal A C, and A X=100 yards, therefore, A C=200 yards.

The heights of any buildings which stand upon a horizontal plane, may be determined in a similar manner, care being taken to allow for the observer's height above the base of the building.

Example.—A X is a pyramid standing upon the horizontal plane A B. The altitude of X is required above the plane A B.

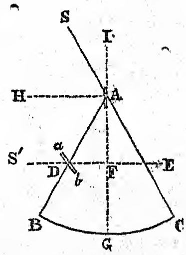


Upon the face of the pyramid make a mark C, equal to the height of the eye. Set the sextant-index to any convenient angle in the division table, say 45°, pace back from C, so that X and C are in the same vertical plane, and until the marks C and X coincide in the horizon-glass of the sextant. Set up a staff at D with a mark equal to the height of the eye, and pace back in the production of the

line C D, until E, another point is reached, from which D and X, coincide in the sextant-glass, when 26° 34′ are used. Measure D E, then the angles used being 45°, and 26° 34′, the whole numbers corresponding to each being 1 and 2, then D E, being multiplied by the difference between 1 and 2, will give the vertical height of X above the level C. Thus, if D E were 400 feet, then X would be 400 feet above the level C. Then add the vertical height of C, say 5 feet 4 in., and 405 feet 4 in. would be the true vertical height of the pyramid.

THE PRINCIPLE OF THE SEXTANT.

Suppose A B C a sextant, A G the index-arm, B C the graduated arc, A the index mirror, D the horizon glass, E the position of the eye when observing, S any object, S′ any other object.



Then the angle S A H or S E S′ will be double the angle G A C, measured on the arc B C.

Draw A H parallel to E S′, then, because the angle of incidence is equal to the angle of reflection, therefore, B A G=S A I, also b D E=a D A; and since C A is parallel to a b ∴ from the above D A E=D E A. H A I=D F A=F A E+D E A, and D A E being equal to D E A, then H A I=D A E+F A E. From H A I and D A E+F A E, take the

equal angles S A I, D A F, and there remains S A H=F A E+F A E=2 G A C. That is, the angle between S′ and S is equal to twice the angle G A C. Thus, to show the true angle between S and S′, the arc B C must be graduated to show double the number of degrees due to the arc of a circle of similar extent. Hence the sextant shows 120°, on an arc of 60°.

THE PARALLAX OF THE SEXTANT.

The term "parallax of the sextant" has been made use of to denote the difference which exists between the position of an object seen by reflection from the index-mirror, and seen direct by the eye. Thus, if an object be quite close to the sextant, it would not be seen as one object in the horizon-glass when the index was at zero, but the index would have to be moved on the arc of excess to obtain this effect. Therefore, when taking angles to any near object, we should, if possible, direct the sight upon the near object, and bring the distant one to coincide by reflection.

Except when taking angles to any objects within 100 or 150 yards of the observer, parallax would produce too trifling an effect to be worth noticing.

The real effect of the parallax of the sextant is to cause angles of about from 0° to 20° or 25° to be read less than they ought to be, beyond this point the angles indicated on the arc would be greater than they ought to be; whilst at about 30°, parallax produces no effect.

CHAPTER VI.

HILL SKETCHING AND CONTOURING.

Every military sketch should have represented upon it, the various irregularities of ground, such as hills, valleys, gravel pits, &c. A sketch with these features of country depicted upon it, is called *a topographical sketch.* Topographical drawing, being the art of representing upon a flat surface, the slopes and form of hills.

Hill sketching should not be attempted until the various roads, rivers, and other stations, have had their relative positions determined.

The course of rivers, or streams, is almost invariably in the lowest part of the country, along which they run, and thus the "*water course,*" as it is termed, will, when sketched upon paper, determine the course of the valleys.

A small stream, or even the dry bed of a stream, down which water flows only after heavy rains, will enable us to trace the main course of a valley; then these "water course" lines should be carefully traced on the sketch, when we purpose representing the hills.

F

The highest points in a country should next have their positions determined, and to enable us to do this, we may make use of two, or more known points, from which to interpolate, provided that there is no station on, or near to the various elevated points, which may be made use of for the same purpose.

When the lowest parts of the country represented by the "*water course*" lines, and the highest parts called the "*water shed,*" have had their positions fixed, the general outline of the hills, and valleys, can be at once sketched.

METHODS OF REPRESENTING SLOPES OF GROUND ON PAPER.

There are various methods of representing the slopes of ground on paper. A common camel hair brush is sometimes used with which to wash on a shade of Indian ink, or sepia, where the ground slopes, the darkest shades being intended to represent the steepest slopes. These washes of dark colour are shaded off into the valleys, so that the highest ridge, or "*water shed*" line, is represented by a darker shade than the lower, or "*water course*" line.

Many suggestions have been put forward, with regard to representing the slopes of hills by means of a particular degree of shade, and thus with the addition of water to each saucer of colour, a scale of shade may be made use of. These methods are very ingenious in theory, but fail most signally when

applied in practice, especially in the field; besides which, when several individuals are sketching portions of ground which are to join in one sketch, it is almost impossible to obtain an uniform scale of shade.

A simple wash of sepia will however serve to roughly represent the irregularities of ground, when there is not time for any more correct method. The level ground is then left free of colour, whilst the slopes of the hills are darkened.

CONTOURING.

A far more correct system than the preceding is that known as contouring. It is here supposed that a series of parallel and horizontal planes, cut the land at certain equal vertical distances, and that the lines of intersection are then traced over the country, and numbered according to their vertical distance above some fixed datum. The same effect might be represented, if we placed a model of hilly ground in a vessel of water, and then at intervals lowered this water a certain distance, tracing out on the model the water line, each time that the water had been lowered. The model would then be contoured; that is, it would be covered by a series of horizontal lines, each of which was at the same vertical distance from the other.

In consequence of each of these lines representing a certain vertical distance, they will vary in horizontal distance inversely as the steepness of the

slope. Thus, if the contours were ten feet apart in vertical distance, a slope, such as that represented at A F, fig. 1, would be shown on the plan by two

Fig. 1.

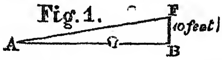
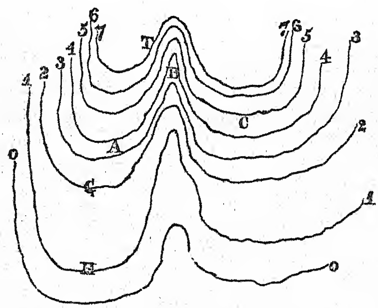


Fig. 2.

contours, distant in horizontal measure equal to A B; whilst in fig. 2 the vertical distance F D of ten feet, would be shown by a horizontal distance equal to C D; the slope of the ground being supposed such as C F.

The method of representing the steep, or gradual slopes, may be better understood by the following figure, in which we will suppose that each continued line represents the same vertical distance above the next line. This distance we will suppose to be 10 feet. Then the highest contour marked seven, would



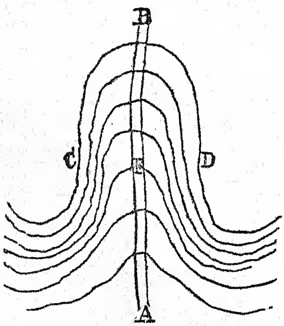
be 70 feet above the contour 0. B would represent a steep valley between two hills A and C.

If we trace the line marked 3 until it forms an acute angle in the valley at B, and then compare this position with that marked T, we shall find that there are four contours between these two points, and therefore a difference in altitude of 40 feet, due to the small horizontal distance T B. The same vertical distance exists between T and A, but the horizontal distance being greater, the slope would not be as great as between T and B.

Between G and H the ground is much more level, as there is merely a difference in vertical height of one contour for the horizontal distance G H.

A few examples of the representation of ground, may here be found of use, to the individual desirous of making a military sketch.

First, we will suppose that a road passes between two steep hills, the rise of the road being gradual.



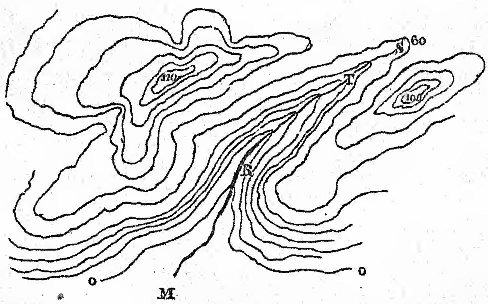
The annexed figure will represent a road under these conditions. The road rises from A to B, and the summit of the hill is reached at B. The hills C, and D, upon each side of the road, are upon the same level as B, consequently a point such as F in the road, would be the distance of 4 contours in vertical height below C, and D, as well as the same distance below B. The

remaining ascent to the summit of the hill, is obtained on the road by the horizontal distance F B, whilst the same height is gained at the side of the road in a much shorter distance, viz. F D, and thus the slope at the side, is much the steeper of the two.

By looking at this diagram from the direction B, it will be seen how a representation may be made of a road, that *descends* between two steep hills.

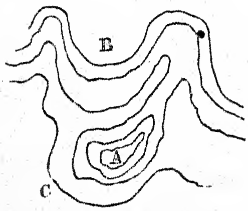
Sometimes a road passes along the side of a hill, and is quite level. When this is the case a contour would be drawn parallel to the road, but whenever a road ascends, or descends, the various contours must of necessity cross it.

A stream flowing between two hills, would be represented much in the same way. Water will only flow down hill, as long therefore, as we find a stream of water running in one direction, so sure are we that the land must fall in the direction in which the water runs, and that some contours must cross this stream.



S T R M would represent a stream flowing from

S to T, R, and M. The ground will here fall the whole way from S to M, the hills on either side being higher than the bed of the stream. As the hills bend from side to side, so will the stream turn. Thus, if we sketch the course of the stream, it may be at once seen how great an aid this would be to us, when we purposed sketching the hills. When the stream flows very rapidly, the contours will be found close together, the stream is then usually narrow. When, however, the water moves sluggishly, and the stream is broad, as shown at R, there will be scarcely any fall of ground, consequently the contours will be found much farther apart. By paying attention to some of these trifling details the general form of the slopes may be soon sketched without any instrument.



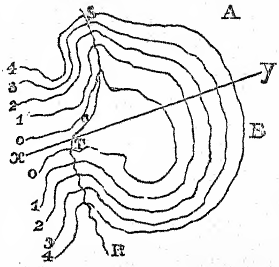
It sometimes happens that a hill is isolated, and that whilst the distant ground is all higher than this hill, still the ground falls for a certain distance all round. When this is the case the contours would be drawn as shown in the last sketch; B would represent the crest of a hill sloping towards C, whilst A would show that there was an isolated hill, the top of which was A.

IMPOSSIBLE CONTOURS.

By knowing how errors in contouring may be

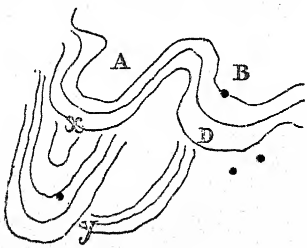
observed, we may probably avoid committing these errors. It is by no means unusual to find the tyro in sketching, place upon his sketch a representation of ground which is impossible, and in imperfect military sketches such anomalies not unfrequently escape the detection of the inexperienced. That which is called impossible contouring, is when two or more contours are drawn, which we will call 1, 2, and 3, 3 being the highest contour. Then in the course of the sketch number 3 is found to represent a lower contour than either 1 or 2. The following example will aid to explain this anomaly.

We will first examine the contours above the line x Y, we then find a stream running from S to R. The contours are represented by 0 1 2 3 and 4, 1 being a certain vertical height above 0, 2 the same height above 1, 3 above 2, and so on. If the contours were joined as represented in the direction Y, we should have these contours numbered as shown below the line X Y. The stream T R we have assumed as already correctly sketched and flowing in the direction T R. As 1 contour is above 0, and 2 above 1, we can by tracing these contours find that below the line X Y, we have represented the water flowing *up hill*, consequently these contours could not join as shown



in the sketch, and some error must have been committed. It would be probable in such a case that the contours above X Y sloped in the direction of A, whilst those below, turned in the direction of B, and continued to represent a fall in the land.

Unless the ground is intersected by perpendicular cliffs or pits, the contours cannot terminate suddenly; thus undulating ground should not be represented as shown below, some of the contouring being there impossible.



Suppose A and B hill tops, sloping towards X and D, then such contours as those shown at D and Y, and also at X would be impossible. Some portion of this ground must have been carelessly sketched, or not correctly observed, for these disjointed lines, would not represent any description of hill or valley. A contour line once drawn, can only terminate by rejoining itself as in the case of an isolated hollow, or hill, or by passing beyond the limits of the sketch, and it may thus pass over the country for miles, representing all those points, which are at the same vertical distance above a fixed horizontal plane.

TO ASCERTAIN THE SLOPES OF HILLS, OR NUMBER OF CONTOURS.

The angle which the slope of a hill, makes with the horizon, may be very readily determined by fastening a weight to a thread, which may then be attached to the centre of the protractor, on the side upon which the degrees are marked. When the protractor is held horizontally, this plumb-line will coincide with the 90° on the protractor. When the protractor is inclined 10° to the horizon, then the plumb-line would mark 10° *from* the 90°, and so on. By holding the top of the protractor parallel to the slope of the hill, the angle which the slope makes can thus be ascertained. When we know the slope of the hill, we know the horizontal distance between the contours, as each horizontal distance would represent the base of a right-angled triangle. Thus, if the slope of a hill were about 5°, the horizontal would be to the vertical distance as 10 to 1, and thus 10-feet contours would in horizontal distance be—

for	7°	about	8	to	1	or	80	feet apart.
„	$9^\circ\frac{1}{2}$	„	6	„	1	„	60	„
„	$11^\circ\frac{1}{3}$	„	5	„	1	„	50	„
„	14°	„	4	„	1	„	40	„
„	$18^\circ\frac{1}{2}$	„	3	„	1	„	30	„
„	$26^\circ\frac{1}{2}$	„	2	„	1	„	20	„
„	45°	„	1	„	1	„	10	„

THE CONTOURING GLASS.

For ascertaining the number of contours, a simple and very handy little instrument is made, and sold, by several instrument makers, and called a contouring-glass. A common brass tube contains a reflecting glass, arranged so that the bubble of a level placed on the top, is seen through the tube, when the tube is held horizontally. Thus, by looking at the ground in any direction, a point can be obtained which is on the same height, as the eye of the observer. Assuming the eye to be about 5 feet, or 5 feet 4 inches from the ground, we thus obtain a difference in level equal to that amount; we can then pace to the spot thus obtained, and direct the glass to the next point, and so on. The number of contours required to represent any hill, can thus be readily obtained, and also the relative altitudes of the various points. If a check be kept in the field upon the contours which are above, or below a given point, and if each contour that is a rise, be denoted +, whilst those which represent a fall be marked —, it will soon be found, where several contours of the same number cross the country, and if these belong to the same hill, their junction will represent the form of the slopes. When entering the numbers on a finished sketch, they must all be marked *above* the lowest point on it, or above some known point below, as zero.

THE SCALE OF THE CONTOURS.

The scale of the contours must be regulated by the scale of the plan or sketch. If the scale of the sketch be large, then the contours may be placed at a less vertical distance than if a small scale be used. Such a proportion should be adopted that the contour lines do not entirely hide the other details of the sketch, and yet represent fairly the nature of the ground. The following is considered the most suitable scale:—

From 6 inches to 1 inch to a mile, contours about 25 feet apart.

For larger scales, contours 10 feet apart.

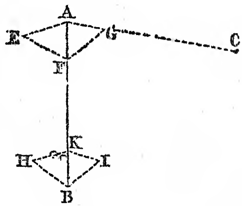
CHAPTER VII.

SKETCHING WITHOUT INSTRUMENTS.

INSTRUMENTS are merely the aids by which we measure the angular distance between objects. If, therefore, we are unprovided with compass, sextant, or other instrument for measuring angles, a sketch can still be made, if we have pencil and paper. If, in addition, a protractor be in our possession, we may proceed much in the same manner as when provided with the compass, or sextant. It would not be difficult to make a rough protractor on paper, or to make this protractor hard, by gumming together a number of pieces of paper. The divisions which denote degrees, need not be marked with mechanical accuracy, but a close approximation might be obtained. The semicircular protractor could be the more easily constructed, two pins and a piece of string serving as a pair of compasses with which to describe a semicircle.

The base line may be measured upon any suitable ground, and the angles from either end of the base, and to any remarkable objects may be approximated

to, by either or both of the following methods, so that a check may be kept by the one, upon the other. Suppose A B the base line, which has been paced, and C, and D, two distant points, the positions of which are required. Select any point (or make a



mark) at G, in line with A and C, and distant about 50 or 100 paces, C we will suppose being about 1000 paces from A. Then pace a nearly similar distance to A G along the base A B. Suppose A F this distance, then pace F G. Thus, having the distances A G, A F, and F G, we can construct this triangle upon A F, and the side A G is directed upon C. In like manner at B, the point I must be selected, so that B I produced, will pass through C. Thus, the intersection of A G and B I produced, will determine the point C.

In like manner, D and any other points might have their positions fixed, and the details might be sketched by pacing from point to point.

Another method by which to approximate to the angles, and one which has been underrated by those who probably did not use sufficient caution in their trials, is by means of a pencil, or protractor, held at arm's length, and horizontally. The angular distance

which this pencil, or protractor, subtends when held *at one fixed distance* from the eye, having been ascertained, the number of protractor's distances between any two objects, will enable us to approximate to the number of degrees. Some details may here be requisite.

In the first place, the protractor must always be held at the same distance from the eye, a proceeding which can readily be accomplished by means of a piece of string, or thread, fastened to the protractor, (by a hole in the centre of the protractor is best). Upon this string a knot should be made at the usual distance that the protractor is held. This knot may then be held to the side of the eye, with which we observe the distance, covered by the protractor. As we shift the protractor its own length, from point to point, this string should remain tight, and thus an uniform angular distance will be subtended. When any person is provided with an instrument, it is very easy to find by trial how many degrees a 6-inch protractor, or any other article of a different length, would subtend, when held at a certain distance from the eye, and thus he might be prepared for a contingency. We can, however, find how many degrees any object subtends when held at arm's length, by selecting any point on the horizon, and moving the object that we hold, its own length, and so on, until we come to the same point again. We can then divide 360, by the number of times that we have moved the object; the quotient will give the number of degrees subtended. With a very little practice,

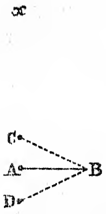
and great care that the protractor is held at the same uniform distance from the eye, an observer may obtain a very close approximation to the real angle between two objects.

When sketching along a line of road without instruments, every opportunity should be taken to obtain a distant view of the road, and thus its main direction may be sketched by eye. If no distant view can be obtained, the bends of the road must be estimated by the eye, or if the sun be shining, the angle formed by the shadows of vertical objects may serve as a guide. When working upon a long and circuitous road the sun will be found of great use, to check the assumed direction; for as the sun on an average, moves from east to west, at the rate of about 15° in each hour, our own shadow would enable us to approximate to the bearing of the road.

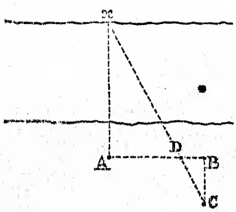
It is when a sketch of this description is to be made, that the judgment, ingenuity, and fertility of resources of an individual are put to the test. No absolute rules can be laid down as guides when the means are very limited, but every advantage should be taken of those at our disposal.

A piece of stout string, or a thin piece of cord, about 50 or 100 feet long, is very useful in case we require to measure the distance across a river, or to any object which may be inaccessible. By means of this rope we may lay off on the ground many useful angles; a right angle for instance would enable us to obtain the distance with great ease.

To set off a right angle from any point A, and at



right angles to A x, we should measure an equal distance on each side of A, and in the same straight line as A x, this equal distance being less than half the length of the rope. Let C and D be these points. Fasten the ends of the rope at C and D, and having ascertained the centre of the rope by doubling it, the centre should be drawn out towards B, until D B and C B are tight. Then x A B will be a right angle. When we are able to set off a right angle to any line, the distance across a river may be obtained as follows :—



Suppose x A the distance required. Then from A set off A B at right angles to x A, by means of the rope, and one or two upright sticks to mark the line. From B set off B C at right angles to A B; take any point D in A B, and note the point in B C, where x and D are seen in the same stright line. Then measure with the rope, or pace, B C, B D, and A D. We then have the following proportion; as B D : A D :: B C : A x. If, therefore, A D were 200 paces, B D 50, and B C 100, then A x would be 400 paces.

An angle of 60° can be set off, by doubling the rope into three equal parts, and then fixing these parts into the ground, so that each side of the triangle is drawn tight. 120° may then be set off

by producing one of these sides, in the opposite direction. Either of these angles would serve equally as well as 90°, provided the ground were suitable. With the choice of the three, and also the option of either side of the line A x for the construction, any local difficulties might be overcome.

Several other methods might be mentioned by which to obtain distances. It is far better, however, that the student should make himself thoroughly conversant *in practice*, with one or two methods, than to be superficially acquainted with the principles, of one or two dozen. When the latter instance happens, an individual, if suddenly called upon, is helpless without his books of reference, whilst in the former, the work is readily executed when required.

A small piece of thread, and three or four pins, will enable any person to practice upon the floor of a room, the preceding examples, and the amount of accuracy attained, if the work be carefully done, is often surprising.

Thus, a sketch without instruments, can be accomplished by means of a few expedients, and when accuracy is not very essential, the work may be done with as great rapidity as though a compass or sextant were used.

JUDGING DISTANCES.

It is a great aid, when sketching without instruments, to be able to judge distances with tolerable

accuracy. A little practice will soon enable individuals to judge up to 200, or 300 yards, with a probable error of from 5 to 10 per cent. The best method is, to commence by judging short distances, such as 30 or 40 paces; then pace this distance, and so on, until we can judge a hundred yards with tolerable precision. When required to judge a long distance we should not look at once at the extreme point and then estimate the distance of this point, but we should judge where the first fifty yards would be, then where the 100, and then take distances beyond of about 100 yards, until the object was reached. Nothing but practice can aid a person in this matter, but as nearly every individual takes a walk daily, there is no lack of opportunity for practice.

Sometimes an approximation may be made to a distance by observing the height, that some known object appears upon a pencil, held at arms length; thus, assuming a man to be six feet in height, with his hat or cap, we should have a proportion between the distance of the pencil from the eye, and the height that the man appeared on the pencil, and between the height of the man and his distance. It is better however to train the eye to judge of distances independent of these rough aids.

The usual rate at which a person walks, or rides, may enable us to judge how far we have gone, when we are travelling long distances, a correct account being kept, of any stoppage which may be made on the journey.

A very close approximation may be made to distances by means of the velocity of sound. Sound travels at the rate of about 1140 feet per second, thus the time which elapses, between the flash and report of a gun, will enable us to estimate the distance.

To count seconds, however, we should have a watch, and without it there is no check upon the estimated interval of a second. Even with a watch, we cannot look at the flash of the gun, and the second hand at the same time. For actual practice I have found the following a very simple and accurate method:—

"Mark time" with the feet, at the rate of a *quick* march, then watch for the flash of the gun, count the paces between the flash and report, and multiply these paces by 210, the product will be the distance in yards.

Thus, if we counted 9 between the flash and report, 1890 yards ought to be the distance.

The time for the paces, can be readily obtained by remembering the "air" of some quick march.

If this process be tried once or twice, and allowance made for half paces if required, the distance of a mile, or a mile and a half, could be obtained within at least 200 yards.

Thus, two individuals might select convenient stations from which to take angles, obtain their distance by means of two or three rounds of blank cartridge, and form a rough sketch of the principal objects, (*previously agreed upon*) without quitting their positions.

CHAPTER VIII.

MILITARY RECONNAISSANCE.

A MILITARY reconnaissance, means the process of examining in detail, the peculiarities of a country, and of procuring every information which could in any way be of service to a General, who proposed conducting operations in or near that country.

An individual who purposes to make a reconnaissance, should imagine himself to be in the position of the commander, who is about to move a large body of troops, into any country where it is probable that he may encounter an enemy. He can then reflect upon the principal points about which it is necessary that he should possess information, and it is therefore to these points that his attention should be directed.

Let us suppose that an army composed of artillery (heavy and light), of cavalry and infantry, is to be moved from one point to another. Let us call these two points A and B, and let us reflect upon the information which we ought to possess, before we commence to move.

The various arms must march, consequently we

must know which are the best roads between the two points A and B. If the roads are very good, hard, and level, the heavy artillery may be moved along them without much difficulty. If, however, the soil of the roads be of such a nature, that a very heavy fall of rain would render them impassable for heavy guns, it is of great importance that we should know this fact, and also the time of year when the heaviest rains are most common.

A long line of troops, proceeding by one road, would occupy a considerable length of time, and rapidity of movement might be of great importance. Probably there might be some bye-roads, beaten tracks, or even open country, along which infantry and cavalry might travel, whilst the best road would serve for the artillery alone. The difference in distance between these routes, should be ascertained by personal trial, if possible.

There might be some cross country route, which, in its present condition, although not passable for cavalry might be readily rendered passable. A few brick walls might stop the way; some palings, or other impediments, which could be disposed of with the aid of a few bags of gunpowder, or two or three crowbars. A very hard piece of ground, over which artillery might travel, might be intersected by a series of drains or water-courses, which would effectually stop the transit of artillery. Within a short distance there might be a wood, in which fascines might be constructed, and which, if thrown into these water-courses, would enable the artillery to

pass. It might be necessary even to convey some planks and supports; if so, information upon this point should be given.

It should be borne in mind that whilst heavy artillery require a good road along which to travel, light artillery may be moved in almost any country; that cavalry, and infantry, can traverse mountain-passes and byeways, which would be considered impracticable for them by the uninitiated.

If we purposed sending troops by any particular road, it would be necessary to know whether an enemy might not take advantage of some favourable position, from which the line of road might be commanded, and thus the size and nature of the woods upon each side of the road should be noticed, as also the hills and ravines, and the means by which they could be approached or turned, if occupied by an enemy. The various buildings on either side of the road might, if of strong masonry, and loopholed, require artillery to destroy them, or to dislodge any troops therein. Thus, farm-houses, country residences, and detached villas, should be carefully examined.

The directions of the principal towns, or villages, should be pointed out in a reconnaissance, even though the towns may not appear on a sketch, and the names of the various places to which branch roads lead, should be clearly written.

The rivers, canals, and water-courses of every description, should be accurately described. The breadth, depth, nature of bottom, description of

water, and liability to floods, being all matters of importance. The fords, or possibility of making or destroying fords; the bridges, and possibility of repairing, making, or destroying these; the means at hand for making rafts; the steepness of the banks of the river, and their nature,—whether rock or clay, &c.,—should all be reported upon.

The mountains and hills should be most carefully reconnoitred. The woods, clumps of brushwood, precipices, passes, pinnacles, and necks of lands, should be examined; the means of passing from one elevated point to another, or of rendering any such passage impassable, are of importance to be known. When any villages or towns are examined, the report should mention the probable amount of accommodation which could be afforded to men and horses, both for permanent quarters, and on a march; the means of obtaining supplies for the troops; the character of the inhabitants,—whether disposed to aid or oppose the soldiers; the distance of the nearest towns or villages, and any other information which, in the judgment of the individual, making the investigation, might be of aid to a General.

The best military positions, whether for the advancing or defending army, and the general nature of the ground and enclosures near these positions; the camps, or bodies of troops, near the proposed line of march; the various reports prevalent amongst the inhabitants; the probability of these being true; the means of obtaining forage for the horses, firewood for the troops, water for men and cattle, and therefore

the best places at which to halt, are all subjects to which attention should be directed when a reconnaissance is being made.

It might be supposed that success, or failure, in large military undertakings, depended upon some brilliant movement being made, or some dire mistake being committed. History, however, points to the fact, that they both mainly depend upon attention to, or neglect of, those things which may be called mere common-sense matters. This point should be remembered when reconnoitring.

TO MAKE A RECONNAISSANCE.

When possible, good guides should be chosen to accompany the individual making a reconnaissance. Wood-rangers, shepherds, smugglers, or sportsmen, are usually well acquainted with the country around them. A map of the country should be procured and tested. To test a plan, we may observe the intersection of two or three prominent objects, and note whether these agree with actual facts on the ground, or we may take any small portion of the plan, and examine this on the ground which it professes to represent.

It must be left to circumstances, and to the judgment of the individual, whether it is better to take a large, or a small escort, when he reconnoitres, or whether he proceed on foot, or on horseback.

If the principal object of the reconnaissance be to ascertain the number and position of the enemy, an

officer should place himself in a commanding, and concealed position, and, if possible, in front of the enemy when they are stationary, and upon their flanks when they are in motion. The number of batteries, squadrons, and battalions, should be counted, and their positions marked upon the map if they are stationary. An officer selected for a reconnaissance should be acquainted with the language of the country. He should be possessed of good eyesight, should be cool in emergencies, and ready at resources, and he should never forget that to obtain, and to convey information, either about the enemy, or the country, is his sole object. Needless risks, or unprofitable collisions with the enemy, should therefore be avoided. He should wear an invisible grey overcoat, but always have his uniform beneath, to avoid the fate of a spy, if taken.

If the reconnaissance is to be made on horseback, the officer should be an excellent horseman, able to ride across country if required. He should also be mounted upon the best horse that can be procured.

Immediately any information is gained, it should be clearly written down, so that nothing be left to the memory. When, however, the country people are being questioned, it is better that they should not see that notes of their replies are being taken, otherwise they may become cautious, and avoid direct answers.

When moving from point to point, the most sheltered and retired roads, or paths, should be followed; every advantage should be taken of commanding

positions, from which to examine the road, or path, along which an officer purposes to travel.

A good telescope is an essential part of the reconnoitring equipment.

Rapidity is one of the most important requisites in a reconnaissance; but care should be taken that hurry be not mistaken for rapidity. That individual who in a given time, can obtain the greatest amount of information about a country, or an enemy, is the most efficient reconnoitrer.

To write the report of the reconnaissance, in a clear and pithy style, should be one object of the individual employed. A multiplicity of words should be avoided, for it should be remembered that the General, or other officer, who might read the report, would not have unlimited time on his hands. It should be our endeavour, therefore, to give as much information, and occupy as little time about it, as possible.

Under the following heads will be found a summary of the information required :—

ROADS.

Their breadth; whether they are gravelly, stony, sandy, or clayey; where they lead, from and to; whether they be crossed by streams or rivers; and whether they might be easily blocked up with the aid of trees, large rocks, &c.

RIVERS.

Breadth; depth; rapidity of current; whether navigable, and for what distance; nature of bottom;

style of bridges; best places for crossing in boats; probability of fords; description of banks; means at hand for making rafts; whether tide or rains affect the river; if so, to what extent; also the houses, mills, and buildings on the banks.

MARSHES.

Of what extent; whether crossed by roads or paths; whether these are always passable; whether the water is putrid or good; whether the marsh is passable for infantry.

MOUNTAINS.

In what direction they run; whether isolated or belonging to a chain; the woods and passes through them; the slope of the road or pass at the steepest part; whether wooded or barren; whether snow is upon them, or likely to be, and at what time: are there streams, ponds, or torrents? what quantity of water; what cottages, villages, and what provisions; are there any guides or herdsmen upon them? are they much frequented by people?

FORESTS.

Their extent; style of brushwood; paths through them; water in them; clearest and densest parts; whether suitable for ambuscades, or to protect an enemy's flanks.

TOWNS AND VILLAGES.

Nature, approximate size, and style of buildings; style of streets; whether broad or narrow, straight

or crooked. Inhabitants—their occupation; whether armed, or likely to be; supplies in the town, whether for men and horses; localities commanding the town.

THE ENEMY.

Their number, position, occupation at time, probability of their moving or halting; apparent strength in artillery and cavalry; situation of alarm posts; number and apparent vigilance of sentries; whether any detached parties are visible; whether any movements appear to be commenced in camp; whether any traces of troops are seen in the woods, or in the country.

Any general remarks which may be necessary, or by which particular information may be given, should be added at the end of the report.

* * * * * * *

It is often found that a landscape sketch of some military position, camp, or portion of country, will give a better idea of the reality, than even a well-executed ground-plan. An outline sketch may be readily made; and, after a little practice in the field, it will be found, that with a few lines, a representation of any country may be made. The first proceeding in making a sketch, should be to select such a position, that the principal important objects may be seen. When representing these on paper, some liberty may be permitted, so that we may represent upon the sketch objects which may not be actually visible from our position, in consequence of trees, a slight hill, or some other obstacle intervening. Perhaps if we moved forty or fifty paces one way or the

other, a battery or some other important object would become visible. To conceal the battery by a tree would not be judicious, although actually on the ground from *our position* the battery might not be visible.

When making a sketch, the most prominent objects should be first selected, and their relative positions marked by a dot on the paper. Then, these objects being sketched, the details may be proceeded with, care being taken that too much attention is not devoted to the mere outline of some trees, or form of ground, which would vary in appearance from every point from which it was viewed.

Thus, one or two outline landscape sketches, will aid considerably, to convey to the imagination of any person, an idea of the ground of which a reconnaissance has been made.

The report may be sent in, written upon common writing paper or foolscap, and if voluminous, attached to the plan of the ground, or separate.

When a line of road has been sketched, and reconnoitred, the plan of the road, and the report, may be prepared in somewhat the following form :—

FORM OF A RECONNAISSANCE.

Villages, &c., on or near the road.	Distances in Miles.		Nature of Road.	Number of Houses.		Quarters.				Water.	Forage.		Provisions	
						Permanent.		On a March.						
	Intermediate Distance.	Total Distance.		Brick or Stone.	Wooden.	Men.	Horses.	Men.	Horses.		Hay.	Corn.	Meat.	Bread, &c.

CHAPTER IX.

THE CORRECT MEASUREMENTS OF BASE LINES.

THE correctness of all surveys, must mainly depend upon the accuracy with which the distance between two observing stations is measured.

The first operation to be undertaken in a trigonometrical survey, is the measurement of the base line, and too much attention cannot be devoted to this important step, for any errors which may occur in this proceeding will be multiplied, according as the survey is increased in size.

It has been already stated, that the base line should be measured upon a tolerably level piece of ground, and that from both ends of the base the principal objects in the surrounding country should be visible. The various instruments used in the linear measurements have also been mentioned; a few details will now be given in connection with the practical use of these.

When the most minute accuracy is required, a base line may be measured by the aid of Colby's compensation bars, for a description of which instru-

ments, see 3rd volume of "Course of Mathematics, Royal Military Academy."

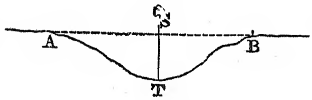
When such instruments are not required, or are not to be procured, glass or deal rods are sometimes substituted, as also the steel chain. For a survey of a district of ten or twenty miles, or for a survey of a colony of even larger extent, and for military purpose, the steel chain will be found a very efficient measuring instrument, provided that proper precautions are used.

When using the chain, we should first ascertain its exact length by means of comparison with some known standard. In all colonial observatories there may be found a standard, which has been tested with the Greenwich standard yard, and thus by observing the temperature of the air, and making any allowance for a change in this, may ascertain the exact length of the chain. It must be borne in mind that it is not only essential that we possess a standard measure, but we must also know at *what temperature* this bar, or chain, represents a standard length. In consequence of all metals being liable to expand, and contract, according to the change of temperature, this information is requisite. At the commencement, and termination of each day's work, the length of the chain should be tested, a proceeding which can be best accomplished, by making two marks upon a wall, or pavement, or by driving two stout pegs into the ground, and marking upon them the extremities of the chain, when it has been tested by the standard measure.

The direction of the base having been agreed upon, it should be laid out by the aid of a theodolite in a straight line, and staves, or marks, left at intervals as a guide to the chainer. The ground over which the chain is to pass, should be freed from all obstacles, such as bushes, furze, little hillocks, &c., as these would prevent the chain from lying straight upon the ground. Each time that the chain is stretched upon the ground, care should be taken that no entanglements ("kinks" as they are called) occur in the chain, as they would shorten the chain's length by fully an inch. At the end of each chain's length an arrow is placed in the ground, outside the handle of the chain; the director brings the handle of his end of the chain over the arrow, and so that the inside of the wire rests against the arrow in the ground. Thus the true length of the chain is measured. Were this precaution not taken, we should measure the length of the chain plus the diameter of the two arrows each time. Whilst using precautions against minute inaccuracies, the chainer should take care that some great error, such as the miscounting of the arrows, or the accidental removal of one of them by the chain, or some other palpable mistake is not committed, such occurrences being not unfrequent in practice, when the attention is engrossed with minutiæ.

When any irregularity occurs in the ground, which is not of sufficient size to be corrected by the theodolite, the true horizontal distance should be obtained by means of a spirit-level and plumb-line,

or by estimating the true level, and finding the true perpendicular by a plumb-line. Thus, if A T B were an irregular piece of ground, and the end of the chain came to S, we could hold the chain so that



S B was horizontal, and find the point T by the plumb-line; the end of the chain might then be held at S, whilst the distance towards S A was being found.

When measuring up or down hill, a correction must be made by means of the angle of depression, which can be found by aid of the theodolite; the method will be explained under the head of theodolite.

Every base line should be measured twice when correctness is required, and even oftener if any great discrepancies are found between the first and second measurement.

When any other apparatus is used to measure a base, every precaution must be taken to avoid those errors to which it may be liable. The comparison with the standard should be made at least twice a day when using a chain, and according to the state of the weather deal rods, glass, or iron rods, or steel chains should be selected for use and tested.

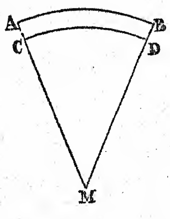
The most accurate implements will never compensate for want of care in manipulation, but delicate instruments in the hands of unskilled operators will

very likely be a source of error and confusion. Thus, for a military or colonial survey of even forty or fifty miles, the steel chain is, in the hands of the average surveyor, preferable to more complicated or more sensitive and easily disturbed instruments.

The ends of the base should be marked by means of some permanent object, such as a large stone sunk in the ground, or a pile driven deep and concealed from average observation. This station could be readily found at a future period, even by interpolation, and might serve as a check, or in case the original survey was required to be remeasured.

When a base line has been measured upon ground which is considerably elevated above the sea-level, a correction must be applied, to reduce the base to its true horizontal distance. The correction is made as follows:—

Suppose M the centre of the earth, and A B the length of a measured base, elevated the distance C A above the mean level of the sea.



Then as M C : C D :: M A : A B : that is the true distance C D would be found by multiplying

A B by M C, and dividing the product by M A.

M C is the true mean radius of the earth, whilst M A is the true radius, plus the height of the point A, above the sea-level.

This correction is very trifling, unless the base is measured on very elevated ground, and is not likely to exceed one or two feet, in five miles.

CHAPTER X.

THE THEODOLITE.

This instrument is generally used for taking the angular measurements in a large survey: for aiding in the measurement of a base line: for finding the relative altitude of different objects, and for traversing along the roads or other continued lines.

The theodolite packs into a box, when not required for use, the telescope being separated from the instrument.

A position having been selected from which to take observations with the theodolite, the legs of the instrument should be separated, so that the screw on the top of the legs is as nearly as possible horizontal. If the ground be level, this will occur when the three legs are equidistant from each other. The body of the theodolite should then be taken from the box, and the upper part held firmly with the left hand, whilst with the right hand the lower part is screwed on above the legs. If the clamping screws be loosened the lower part of the instrument will be found to move freely. The telescope should then be

placed in the supports, the eye-piece fixed in, and the instrument will then appear as shown in the plate of theodolite, with the exception that the eye-piece is removed.

When adjusting or using the theodolite, an individual should not stand close to the feet of the instrument, as the pressure on the ground will frequently cause the instrument to move slightly, besides there being then a chance of a kick or touch disturbing the legs. The telescope T P rests in two supports, marked Y Y, and is focussed by means of the screw M. The eye-piece, which fits in at the end P, must be inserted at such a distance from the diaphram *b. a. d.* that the cross-hairs in the diaphram shall be distinctly visible.

Beneath the telescope, and attached to it, is a level L E. V is a vertical arc, graduated to read minutes upon one side, whilst upon the other the difference between the hypothenuse and base is shown. This arc will admit of being moved so that elevation or depression may be given to the telescope.

Two screws, C C′, refer to the vertical arc. When C is loose, the arc can be moved freely, but when C is tightened, the arc cannot be so moved, but a slow motion can be given to it by means of the screw C′. C is called the clamping screw; C′, the tangent or slow-motion screw; these two screws referring solely to the vertical arc V.

Beneath the vertical arc is the compass-box, in which is the magnetic needle, which is thrown off its centre by means of a lever at the side of the instrument.

Two horizontal circular plates O H, play freely one above the other. On the upper or vernier plate O there are two spirit-levels S S, by means of which this plate is levelled. The lower plate H is graduated to degrees and half degrees, or to degrees and one-third of a degree, or even to a smaller fraction, according to the size of the instrument.

Connected with these plates there are two screws B B′, one of which, B, is a clamping screw, the other B′ is a slow-motion screw. When B is loose, the two plates O H can be moved separately, but when B is tightened, they can only be separately moved by means of the slow-motion screw B′. Two verniers are placed 180° apart on the upper plate O.

Beneath these two horizontal plates there are two screws A A′, one of which, A, is a clamping screw, the other A′ the tangent or slow-motion screw. When the screw A is loose, the whole of the upper part of the instrument above the screw can be moved round in any direction, the horizontal limb then moves upon a double conical axis upon which it rests. If the screw A be tightened, then the upper part can be moved only by means of the tangent screw A′, which will give a slow motion to the upper part of the instrument.

As an aid to the memory we may divide these screws into three sets, in each of which there is a clamping and a slow-motion screw—the upper set belong solely to the vertical arc. The centre set B B′ belong to the horizontal plate O. The lower set, A A′, refer to the whole of that portion of the instrument which is above them.

Below the two screws A A′, there are two brass plates KK, which are separated by four screws G G G. By means of these screws the horizontal limb is placed truly horizontally; the process will be described presently.

The theodolite is an instrument, a knowledge of which cannot be acquired in a few minutes, it is therefore advisable that an individual should proceed systematically to make himself acquainted with the names and use of the various portions. First, the names may be acquired, secondly the use of each portion. For the names we may begin at the upper portion of the instrument, where we find,—

The telescope T P.

In the interior of which, at P, is the diaphram to which the cross hairs are attached.

The eye-piece of the telescope is fixed on beyond P.

Y Y the supports of the telescope, termed the Y's, L E, the telescope-level.

V the vertical arc.

C the clamping, C′ the slow-motion or tangent screw to the vertical arc.

S S the horizontal plate levels.

O and H the horizontal plates. O the vernier plate, H the lower plate.

B B′ the clamping and tangent screws of the upper horizontal plate.

A A′ the clamping and slow-motion screws for the conical axis, or lower horizontal plate.

K K the parallel plates.

G G G the parallel plate-screws.

Below the junction of the legs there is a hook for suspending a plumb-line.

When we purpose to use the theodolite, the first proceeding should be to push in the eye-piece of the telescope to such a distance that the cross-hairs in the diaphram are distinctly visible, this arrangement can only be affected by trial and error, but it can be accomplished in a few seconds.

The vertical arc being free, the telescope should then be directed upon some distant, well defined object, such as the spire of a church, or the top of a flag-staff. The vertical arc should then be clamped, as well as the horizontal plates, and the body of the instrument; and the adjustment of the cross-hairs should be made, this is called

THE ADJUSTMENT FOR COLLIMATION.

The intersection of the cross wires being made to coincide with the distant object, when the telescope is in its ordinary position, with the level below, the telescope is then turned half round in its Y's, so that the level is above it. The object of this proceeding is to find whether the wires intersect exactly in the axis of the telescope. If they do intersect at this point, then, when the level is uppermost, their intersection will still coincide with the selected object. If they should not, then will the object be seen either above or below their intersection. When this occurs, the opposite vertical screws on the exterior of the

telescope, at P, should be moved, first loosening one before tightening the other; these screws will alter the position of the diaphram, and half the difference should be thus corrected; the other half, by means of the tangent-screw of the vertical arc. The operation should be repeated until no difference exists; then the line of vertical collimation is complete.

A similar proceeding should then be adopted for correcting the horizontal line of collimation, and when the telescope will bear an entire revolution without altering the relative position of the intersection of the cross wires and a distant object, the collimation adjustment is effected.

When taking the altitude of an object, we may avoid any chance of error from this source if we take the reading on the vertical arc, both with the telescope in its usual position, and then with the level inverted. The mean of the two observations will thus be the true angle, independent of collimation error.

The adjustment for collimation is called the First Adjustment for the Theodolite; the second is

THE ADJUSTMENT OF THE TELESCOPE-LEVEL.

It is necessary that this level should be parallel to the adjusted line of collimation, or true optical axis of the telescope. The clips for securing the supports that hold the telescope should be thrown open, and the bubble of the spirit-level brought to the centre of the level by means of the slow-motion screw C′.

The telescope should then be lifted out of its supports, and reversed, this operation being performed with the greatest care, lest any slight touch should cause the instrument to move. When the telescope has been reversed, the bubble should again resume its former position in the centre of the tube, if the level is parallel to the line of collimation. If it does not, it should be brought *half-way* towards the centre, by means of the capstan-headed screw R, which elevates or depresses the level. The tangent-screw C should then be made use of to bring the bubble completely to the centre of the tube. This operation should be repeated, two or three times, until the adjustment is complete, the observer taking every precaution lest the instrument be moved during the reversal of the telescope.

The third adjustment is for the purpose of making the axis of the horizontal limb truly vertical, consequently the horizontal plates truly horizontal.

THE THIRD ADJUSTMENT.

The instrument being, as before, on its stand; the telescope is placed so that it is directly over two of the parallel plate screws, G G. The lower part of the instrument is then clamped, and the screw B being loosened, the upper plate is ready to be moved round. The bubble of the telescope-level is then brought to the centre of the tube by means of the tangent-screw C′. The telescope is then turned with the upper part of the instrument, half round,

that is 180°. If the bubble remains in the centre of the tube, the limb is horizontal in that direction. If it does not do so, half the difference should be corrected by means of the parallel plate screws G G, and the other half by the tangent-screw C′. When this reversal produces no effect upon the telescope, the limb is horizontal in that direction. The telescope and upper part of the instrument should then be turned round 90° from its former position, and therefore over the other two plate-screws, and the same proceeding carried on.

When the telescope-level is found to retain its bubble in the centre during an entire revolution of the vernier plate, the horizontal plates, will be truly horizontal. The levels on the vernier plate, if any difference is found after this adjustment, should be brought to correspond with the telescope-level, these levels being adjusted by means of the capstan-headed screw at the end of each of them. Afterwards when the instrument is moved from station to station, these adjustments are not repeated, but the plates are levelled by means of these levels and the plate-screws.

When the telescope-level has been adjusted, and the vernier plate is truly horizontal, it is necessary to note whether the zero of the vertical arc coincides with the zero of the vernier belonging thereto. If it should, there will be no index-error, but if it should not, it is better not to attempt to move the vernier, but merely, on all occasions of taking angles of elevation or depression, to note the amount of the index-

error, and to call this *plus* when the zero of the arc is below the zero of the vernier, and *minus* when it is above. When the angle of elevation or depression is measured, the *sign* of the index-error should be changed, and the amount added to the elevation or depression, care being taken to register the signs of the angles observed. Thus, if the index-error were $+ 3'$, and the observed angle one of $2° 10'$ elevation, we should call this a *plus*; then, by changing the sign and adding, we should have $+ 2° 7'$ for the true angle of elevation. This index-error is usually called the *horizontal reading*, and its effect may be readily understood if we consider that if the zero of the arc were above the vernier zero, there would be an arc passed over before any elevation was indicated on the vernier, or there would be a depression indicated when the telescope was really level. Thus, to take an extreme case, if the horizontal reading were $-1°$, we should, by elevating the telescope $2°$, merely have $+ 1°$ indicated on the arc as the angle of elevation, whereas it ought to be $2°$.

A few minutes' examination of an instrument will do more to make a person acquainted with it than any amount of reading without one. It is advisable, however, to read the description with the instrument before us, and we may thus avoid damaging it by attempting to move immoveable portions of it. Many valuable instruments are damaged by persons anxious to adjust them, and who are entirely unacquainted with the method. We ought to be quite certain that an adjustment is required before we

attempt to make it, and we should then consider how we are to operate before a screw even is touched.

TAKING A ROUND OF HORIZONTAL ANGLES.

The theodolite, being in adjustment, is supposed to be placed exactly over some point from which we purpose to take a round of angles, the centre of the instrument being arranged exactly above the required station by means of its plumb-line. The zero of the vernier is then set accurately at the 360° on the lower plate, the two are clamped, and the whole of the upper part of the instrument is turned until the intersection of the cross-hairs almost coincides with the end of the base, or the object which we purpose calling the zero point. The clamping-screw A should then be tightened, and the intersection of the cross-hairs made to coincide with the distant object by means of the tangent screw A′. When this coincidence is effected, care should be taken that the screw A is not loosened during the round of angles. The zero of the two plates should now coincide, this fact being ascertained before proceeding further.

The screw B, which clamps the two plates, should then be loosened, and the telescope directed towards the first object on the right. When this object appears near the centre of the field of the telescope, the screw B may be tightened, and the exact coincidence of the object with the cross-wires effected by means of the slow-motion screw B′. The degrees

should then be read off from the vernier which coincided with the 360° on the arc before moving the vernier plate. These degrees are inserted in one column of a table. The minutes are then read off from this vernier, and inserted in another column. The minutes from the opposite vernier are also read, and inserted in a third column.

The object of this double reading of the verniers is, that any errors in the graduation of the limb, or in the centreing of the parallel plates, may be corrected. Thus, if the two verniers should show a different number of minutes, the mean of these would be taken.

Thus, for each angle, the screw B is loosened, the telescope turned round to the object, the screw B tightened, and the coincidence of the intersection of the cross-hairs effected by means of the screw B′. A A′ must never be touched during these observations.

The telescope should, lastly, be directed upon the first object, and the angle noted; this angle should, of course, be 360°, but, owing to the unavoidable movement of the smaller theodolites, it may differ perhaps 1′ from this amount.

The zero of the vernier is next set to the 60° on the arc. The lower screw A is loosened, and the telescope turned until the intersection of the cross-hairs coincide with the first selected object; the screw A is then clamped, and the same process is adopted as on the former occasion. The angles ought now to differ exactly 60° from the former set.

but the difference *between* any two angles ought to be the same as before.

The index is then set to 120°, and a third round is taken.

The mean of these three angles between the relative objects is then taken, unless some great error appears to have been committed in any one set, when that set should be rejected. With the larger instruments, where great accuracy is required, eight or ten sets of angles are taken, beginning each time from a different part of the circle.

By this means, either the incorrect graduation or the bad centreing of the instrument will be avoided, and the angles may be used for future calculations.

The name of the object to which each angle is taken should be written, and it is usual to insert the degrees under a column marked θ. The minutes shown by the two verniers under those marked A and B. The table on page 113 represents the form usually employed.

Under the head of vertical angles H R is the column for the horizontal reading; θ the angle of elevation or depression; — when the angle is one of depression; 1 is the column for the reading on the vernier; there being only one vernier to the vertical arc, only one column is required.

Referring to the vertical angles, we should have for "end of base" by first set + 3′ horizontal reading,— 33′ the angle. This would give a depression of 36′.

By the second set we should have a depression of

Magnetic bearing of zero line, 291° · 30′.	Horizontal Angles.									Vertical Angles.						Height of Station, 185 ft. Height of Instrument, 5 ft.
East End of Base.	1st Set.			2nd Set.			3rd Set.			1st Set.			2nd Set.			Remarks.
To Stations.	θ	A	B	θ	A	B	θ	A	B	HR	θ	I	HR	θ	I	
W. End of B.	°	°	°	60°	°	°	120°	°	°	0	0	9′	0	+1°	8′	
Plumstead Church.	22°	7′	7′	82°	6′	7′	142°	6′	7′	–4′	0	–48′	–2′	0	–49′	
Staff on Butt.	124°	31′	31′	184°	31′	32′	244°	31′	31′	+3	0	–22′	+2′	0	–23′	
Wickham Church.	222°	9′	10′	283°	10′	10′	343°	9′	10′	+2′	0	–8′	+1′	0	+9	
Cemetery Spire.	230°	40′	41′	290°	42′	42′	350°	43′	42′							
W. End of Base.	360°	2′	2′	60	2′	3′	119°	59′	59′	+3′	0	–33′	+2′		–35	

37′. Thus, the mean (36′½) might be taken as the true angle of depression for the end of base from the observing station.

FINDING THE THREE HORIZONTAL ANGLES.

The angles, from the ends of the base, having been taken to any object, we should obtain two angles of a triangle, and we might then obtain the third angle by subtracting the sum of these two from 180°. When no other means are at our disposal, we are compelled to adopt this course, but the third angle should always be observed when it is possible to do so.

The sum of the three angles ought then to amount to 180°.

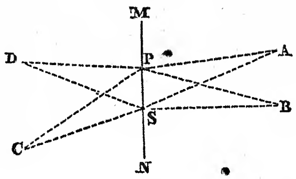
When a large survey is undertaken, and angles are taken to distant objects, the three angles observed will amount to a trifle above 180°, in consequence of the three points being on the surface of a sphere, but this "sperical excess" as it is called, is too small to be allowed for in an average survey made with a 5 inch theodolite.

The three angles being observed, we may judge which set of horizontal angles was the most correct, for that set which brings the sum of the three angles of the triangle nearest to 180°, ought to be the best.

If such a point as the summit of a church-tower has been selected as a station, it may be impossible to make use of the exact spot for the purpose of

observing the third angle. When such a circumstance occurs, the following plan is adopted :—

A point is assumed about ten or twenty feet from the centre of the station, from which the angles ought to be observed. The angles can then be reduced by means of a formula deduced from the following :—



P is the centre of the station, S the "satellite" station near it; A B C D known points, and M N the meridian passing through the stations P and S. Then, in the triangle A P S, we have the exterior angle M P A equal to the two interior, and opposite P S A, P A S. Again, M P B = P S B + P B S. Passing the meridian, the exterior angle M P C of the triangle P C S = P S C — P C S. Also, M P D = P S D — P D S; all these angles being taken in one direction from 0 to 360°.

Again, in the triangle A P B, we have the observed angles P A B, P B A, and the distance A B; we have therefore assumed for the time A P B as their supplement, hence the sides A P and P B are obtained. Also, in the triangle A P S, we have the observed angle P S A, and the sides P S and P A; we have therefore the angle P A S, and consequently

M P A. In like manner we have M P B, M P C, &c. Thus, a table may be constructed, and we simply require to add to, or subtract from, the observed angle (according as it may be over or under 180°) the small vertical angle ascertained by comparing the quotient of the two known sides with the observed angles.

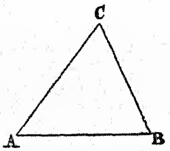
CHAPTER XI.

CALCULATING THE TRIANGLES.

HAVING the measured base, and the angles, or having two sides and an included angle, we may find the remaining quantities in every triangle.

The larger triangles should all be calculated, and the sides laid down on paper by their length, instead of by the angles which they form with the base. Much greater correctness is thus obtained.

The following cases in plain trigonometry are those which will occur in surveying.



A B C is a triangle, of which the side A B is known; also the angles at A, B, and C; it is required to find B C and A C.

Then—

As the side A B
Is to the sine of the opposite angle C,
So is the side B C
To the sine of the angle at A.

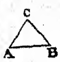
Thus, if we multiply A B by the sine of the angle at A, and divide the sum by the sine of the angle at C, the quotient will give B C.

In like manner A C, substituted for B C, and the sine of the angle at B for the sine of A, would give A C.

The sine of the angle can be immediately found from the tables of sines, &c., and common multiplication employed, if the observer is unacquainted with the use of logarithms. Thus the question becomes one in rule of three, and decimals only.

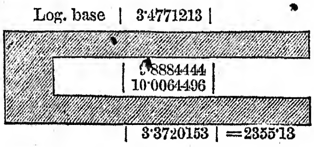
When the surveyor possesses a knowledge of logarithms the process becomes more simple, and by means of the following table the calculations assume a compact and simple form. The sine of an angle A is equal to $\frac{1}{\text{cosec } A}$. Instead, therefore, of subtracting the log sine of one of the angles, we add the log-cosec of the angle, and thus simplify the calculations.

CALCULATION OF HORIZONTAL DISTANCES. BASE, 3000 FEET.

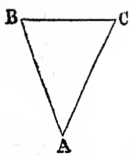
Triangle.	Observed Angles.	Correction if required.	Corrected angles.	Log.	Computation.	Horizontal distance in feet.	Remarks.
No. 1 	A 49° 11′ 0″ B 50° 40′ 0″ C 80° 9′ 0″	O O O	49° 11′ 0″ 50° 40′ 0″ 80° 9′ 0″	Log base= — Sin A= — — B= —Cosec C=	3·4771213 9·8789840 9·8884444 10·0064496 3·3625549 3·3720153	=3000 AB =2304·38 BC =2355·13 AC	

The working of the log computation is made very simple if we cut a piece of paper so as to hide the two quantities which we do not require to add to find the third side. Thus, in the preceding example, a

piece of paper cut as shown below, would make the addition simple.



In some cases we may know the two sides of a triangle, and the angle contained between them. To find the other quantities we proceed as follows :—



Suppose A B, B C, known, and the angle A B C.

Then as the sum of the two sides
Is to their difference,
So is the tangent of half the sum of the two unknown angles
To the tangent of half their difference.

Half their difference thus found, added to half their sum, will be the greatest of the two angles required, which will be the angle opposite the greatest side. The other parts of the triangle may then be found as before.

Ex. A B=2000 feet. B C 3000 feet. Angle A B C 80°.

Then—

$$5000 : 1000 :: \text{tangent } 50° : \text{tangent} \frac{A-C}{2}$$

Hence $\frac{A-C}{2}$ is found, which, added to 50°, will give the angle at A.

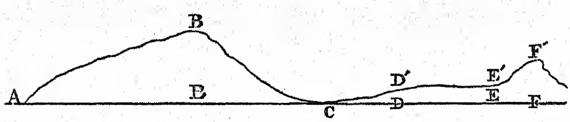
This case may happen when C is an important station, visible from B, but not from A. The distances A B, B C, being measurable, and also the angle at B.

The small logarithm tables before mentioned will be found very handy for this work, when heavier books are inconvenient.

TO MEASURE A BASE LINE WITH THE AID OF THE THEODOLITE.

When a base line of two or three miles is measured, it is almost impossible to obtain a perfectly level piece of ground for the whole distance, consequently if there be hills and valleys across which to measure, the actual distance chained would be greater than the true horizontal distance between the extreme points of the base. We should in fact be measuring the hypothenuse of a series of right-angled triangles, when the base of the same triangles is the distance required.

Thus, suppose A B′ D′ E′ F′ the section of ground



along which we propose to measure a base,

The sum of the distances A B′, B′ C, C D′, D′ E, E′ F′, would be greater than the horizontal distance

A F. A B B′ would be a right angle; A B′ the distance measured; A B the distance required; B′ A B the angle of elevation of B′.

To find the distance A B, we have merely to multiply the distance A B′ by the cosine of the angle B′ A B. To find the height B′ B, we must multiply the distance A B, by the tangent of the same angle.

In practice, therefore, it is merely necessary to place the theodolite in adjustment at A; observe the horizontal reading on the vertical arc, place at A B a staff, on which is a mark equal to the height of the theodolite; take the angle of elevation of B′, then chain the distance A B′. From this we can obtain both A B and B′ B. It is advisable that the distance A B′ should be measured twice, and also that the theodolite should be placed at B′, and the angle of depression taken to A. Thus a check is obtained upon the former measurement and angle.

A regular form ought to be adopted for these measurements in the field, and the table on page 122 shows that which is in most general use.

The two columns on the left refer to the measured distance; the third column to the index-error; the fourth to the angles observed; the fifth to the mean angles; the sixth refers to the stations, from and to, which the measurements were taken. The spaces on each side of the measured distances are left for the insertion of hedges, and crossing the chain line. The first observations, &c., are inserted at the bottom of the table, and the work carried on from the bottom upwards.

MEASUREMENT OF A BASE LINE ON

Distance.		Horizontal Reading or Index error.	Angle of Elevation or Depression.	Mean Angles.	From — To —	Remarks.
1st Measure in Links.	2nd Measure in Links.					
1027	1026 7	+3 +2	—10 +14	+12′ 30″	C to B B to C	
934	932	+3′ 0	+26′ —21′	22′	B to A A to B	

CALCULATION OF THE HEIGHTS AND DISTANCES.

Having obtained the mean distances, and mean angles of elevation and depression, the true horizontal and vertical distances are calculated therefrom. When the measured distance is obtained in links, it is usual to convert this into feet, which is done by multiplying the distance by ·66, the chain being 66 feet in length. This distance multiplied by the cosine of the angle of elevation or depression, will give the true horizontal distance, which, multiplied by the tangent of the angle of elevation, gives the true vertical distance.

The following form will be found convenient for these calculations. In left-hand column ·66 is the assumed length of one link of the chain. If, however, the chain were too long or too short, that is if it were not exactly

CALCULATION OF A BASE LINE MEASURED ON

Measured Distance in Links.	Angles of Elevation or Depression.	Calculation.	Horizontal Distance in Feet.	Vertical Distance in Feet.	Relative Altitude in Feet.	Remarks.
.66 933	Cos. 22	9·8195439 2·969·816 9·9999911			150	Point A 150 feet above Datum.
	Tan. 22′	2·7894166 7·8061547	615·76			
		0·5955713		–3·94	146·06	
·661 1026·5	Cos.22′ 30″ Tan. +12′ 30″					

66 feet in length, then the logarithm of the real length would be taken. Thus, if ·661 were the real length of a link, this number would be made use of. In the second column the angle of elevation or depression is inserted. In the third, the log computation, $\bar{1}$·819 or 9·819—10 &c., being the logarithm of ·66; 2·969, &c., being the logarithm of 933 the distance. 9·999, &c., is the logarithmic cosine of 22′. The number 2·789, &c., is the sum of these three logarithms, and the whole number corresponding will be the true horizontal distance from A to B, this will be in feet, and is 615·76. 7·806, &c., is the log tangent of 22′, which, added to 2.789, &c., the logarithm of the base, gives the log of the vertical height B′ B. This is inserted in the 5th column, and is—3·94, a minus quantity,

as the angle was a depression. A being assumed 150 feet above a datum, the point B would therefore be 146·06 feet above the same datum. The next measurements and angles are treated in the same manner.

ROAD TRAVERSING WITH THE THEODOLITE.

Any convenient starting point may be taken, and the instrument placed in adjustment on this point. The vernier and lower plate should be clamped when the zero of the vernier coincides with the 360° o the lower horizontal plate. The lower clamping-screw A being loosened, the two plates are turned until the needle of the compass points to the 360°, or 180°, in the compass circle. The lower clamping-screw is then tightened, and the *lower* slow-motion screw may be made use of, if necessary, to make the needle point exactly to the 360° on the compass circle.

The theodolite should now be in adjustment. The two horizontal plates should be clamped, so that the zero of the vernier coincides with the 360° in the lower circle.

The clamping-screw of the horizontal vernier should then be loosened, and the telescope directed to any remarkable objects, such as flagstaffs, spires, &c., each angle being read off, from the vernier, which coincided with the 360°. Lastly, the telescope should be directed upon the staff placed at the first bend in the road, which

will be called station B, the first station being called A.

When the telescope is directed to the bottom of the staff at B, the two plates are clamped together. The angle being noted, the lower clamping-screw A is then loosened, and the theodolite is taken to station B, whilst a staff is placed at A. The distance A B, is then measured.

After adjusting the theodolite at B, (but without touching any of the clamping screws) the upper part of the instrument (the two plates still clamped together) is turned so that the telescope is directed upon the station A.

The lower clamping-screw is then tightened, and the upper clamping-screw released, and the vernier plate turned on different points in succession, until the telescope is directed upon the next station C.

The distance B C is then measured, any offsets taken to the right or left if required, whilst the theodolite is carried to C, with the two plates clamped as before.

Thus, as soon as the telescope is directed upon the last station, the *lower* clamping-screw is tightened, and the upper loosened, and as soon as it is directed upon the *next* station, the *upper* clamping-screw is tightened, and the lower loosened.

Instead, therefore, of working with the magnetic meridian as the guide, the graduated arc is the means whereby the various angles are read. The magnetic meridian, however serves as a check upon

any great errors, for when at any station we may move the vernier plate, so that it coincides with the 360° on the arc, and note if the needle agrees with the 360° on the compass card, if it does do so there cannot have been any great error committed.

When possible, angles should be taken from the various stations to the surrounding spires, flagstaffs, &c. For if three or more angles are taken to one point, and when plotted, they all meet at one point, the observations on the traverse, as well as the various distances must be correct. The work ought to be carried round from A, to A again, the "fitting in" of the plot being an additional check upon the work.

PLOTTING THE TRAVERSE.

The most convenient method of plotting the traverse is with a circular card-board protractor, the centre of which has been cut out. This protractor is arranged in a convenient position upon the paper, and by means of a parallel ruler, the angles from any point may be laid off.

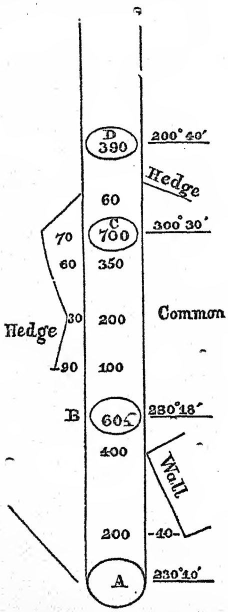
The ruler should be made to coincide with the angle required, and which is marked upon the card, upon opposite sides, the ruler is then carefully moved to the point from which the angle is to be set off, and the line drawn, the length of this line is then marked, and the next angle set off in the same manner.

When the protractor is once fixed, it should be held firmly by weights, and two lines drawn, representing the north and south line, and the east and west line. If it be required to move the protractor to obtain more room on the paper, these lines will serve to readjust it in its correct position. These large protractors are usually divided to 15′, but with care, an angle may be plotted to at least half this amount.

THE OFFSET SCALES.

When much plotting of offsets is required, the offset scales will be found convenient. These scales are arranged so that a small scale slides along the edge of a larger one. The small scale is so arranged that it will move along a line, on each side of which offsets are to be set off, and so that the zero of the scale remains on the line, thus the distance on either side may be at once set off. The distances along the line are obtained by means of the long scale, the zero of which is made to coincide with the zero of the line. Both these scales must be graduated according to the size of the scale employed. When these offset scales are not at hand, the distances may be marked on the line with a common scale, and by means of the protractor, the right angled lines representing the offsets may be drawn, and the distances measured on these lines.

THE FIELD BOOK.



It is essential that there should be one regular form for keeping the field book, so that one person may readily plot the work of another. The form most commonly used is that given on page 128 where the measured distances are inserted between the parallel lines, the offsets to the right or left.

The total distance between two stations is indicated by a circle round the number, thus, 604 would indicate the total distance from A, to B.

The bearing of each station is marked outside the double lines, and with a line beneath, thus, 230° 10′ would show the bearing of the next station from A, and it will be found convenient to write these to the right or left according as the road bends.

GENERAL REMARKS.

When making a survey of a large portion of country, with the theodolite and chain, the number of points to be determined by triangulation, will depend upon the scale to be used. The larger the

scale, the greater number of points should be determined. It is far better to fix the position of a great many points; for triangulation will be found the most correct method, and the points fixed need not be used if not required.

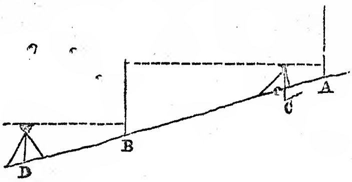
The chain may be used when the details of the survey are to be carried on, to measure any smaller triangles than those which have been calculated. Thus, the frame work is laid down from the measured base, by the theodolite, and the details then filled in with the chain, and the compass or sextant.

For a moderately correct survey of a portion of country, of some 30 miles square, the smaller theodolites might be used, but the larger the instrument the greater the accuracy obtainable.

CHAPTER XII.

LEVELLING.

THE theodolite may also be used to make a section of any line of country. The process is very simple. At any point A, a staff is placed, on which



feet, tenths, and hundredths, have been marked. The theodolite may then be placed at any point C. The telescope-level being truly horizontal, the staff at A is examined, for the purpose of noting where the horizontal cross-hairs cut this staff. The staff is then taken to B, and held vertically, whilst the telescope is directed as before, the difference between the two readings, will give the difference in level, between A and B.

When two staffs are used, the readings on each ought to be compared.

The theodolite is then taken on to D, and the staff at B being turned round, this staff then occupies a position corresponding to A, in the former case; the staff at A is sent forward and so on. The distance from A to B is measured and corrected, for the slope of the ground.

Care should be taken that a staff is placed upon every irregularity of ground, and also that the staves are never more than 1000 feet from the instrument. The levelling may be commenced at either the top or bottom of the slope.

The field-book for this work is usually kept in the following manner, and when plotted, the vertical scale is usually four or five times as large as the horizontal, so that a distorted section will be shown.

Letter or Bench Mark.	Distances in links between stations.	Reading on Staff at		Difference of Level between Back and Forward.		Height above Level of Sea.
		Back.	Forward.	Stations.		
		Station.		+	−	

Check levels may be taken occasionally, by diverging a short distance from the line and returning to it again. This proceeding may be adopted without measuring the distance over which the staves are carried, as it is merely necessary to obtain the

difference in height between two stations on the measured line. If the difference in height be found the same by measuring along the line, and by diverging to the right or left, and returning, the section obtained is sure to be accurate. If the levelling is to be used for contouring, the staff when taken forward is moved about, till the point on it intersected by the cross wires, is exactly some constant quantity, say ten feet above or below the previous reading.

CURVATURE AND REFRACTION.

If two points, A and B, on the surface of the earth, and equidistant from the earth's centre, and therefore upon the same level, be examined from each other with a level telescope, then if A were several miles distant from B, and was observed from B, it would appear below B. Also, if B were observed from A, B would appear below A. This effect is due to the earth being a sphere, the surface consequently curved, whilst the production of a horizontal line would be a tangent to this curve.

The correction in feet due to curvature alone is found to be $\frac{2 D^2}{3}$, D being the distance in miles between the two objects. Thus, the distance in miles of an object being known, this distance is squared, two-thirds of it are taken, and the result is the correction due to curvature.

REFRACTION.

Whenever, from the distance of an object, an allowance is made for the earth's sphericity, it is also necessary to allow for refraction. The amount of refraction is estimated at $\frac{1}{12}$ or $\frac{1}{14}$ of the distance observed, expressed in degrees of a great circle. The following method will be found to give a close approximation:—Divide $\frac{1}{12}$ or $\frac{1}{14}$ of the distance by 101·4; the quotient will give the number of seconds to be subtracted from the observed angle.

Example:—

The distance from A to B was 26400 feet. The angle of elevation, 2°, required the correction due to refraction.

$\frac{26{,}400}{12} = 2200$ divided by $101{\cdot}4 = 21''$ to be subtracted from 2°. If $\frac{1}{14}$ had been taken as the allowance, 18″ would have been the correction due.

When at sea, we may approximate to the distance from any land which is seen upon the horizon, and the height of which is known, by making use of the equation $\frac{2}{3} D^2 =$ correction for curvature, and refraction is allowed for by taking $\frac{1}{6}$th of the value of $\frac{2}{3} D^2$, which is subtracted from this value, and hence D^2 determined.

Example:—

A mountain, 2000 feet above the sea, is visible on the horizon from a boat. At what distance is the mountain?

$\frac{2}{3}$ $D^2 = 2000$ $\therefore$ $D^2 = 3000$, which quantity divided by $\frac{1}{6}$ = 500 to be added.

Distance^2 = 3500, therefore distance = 59 miles.

Example 2 :—

A mountain, 4000 feet high, is visible on the horizon from a boat. At what distance is the mountain?

$\frac{2}{3}D^2 = 4000$ $\therefore$ $D^2 = 6000$. Hence,

Distance^2 = $\sqrt{7000} = 83$ miles.

Example 3:—

Suppose the Peak of Teneriffe 16,000 feet high. At what distance will it be visible from the sea-level?

$\frac{2}{3}D^2 = 16{,}000$ $\therefore$ $D_2 = 24000$. Hence the distance^2 = $\sqrt{28000} = 168$ miles.

THE MOUNTAIN BAROMETER.

The mountain barometer is an instrument, by means of which the approximate altitude of mountains may be obtained. The principle upon which this instrument acts is, that the higher we ascend, the less will be the column of air above us, and consequently the less will be the pressure upon any given fluid. There are several descriptions of mountain barometer, each supposed to possess advantages over all others. A very portable instrument has been invented by Sir Henry Englefield, and possesses many recommendations over those of more primitive

construction. M. Gay Lussac has also invented a very simple and portable sort of barometer. Mr. Newman's portable mountain barometer is also a very convenient instrument.

In the present state of physical science, it is useless to attempt any great refinement for computing heights by means of barometrical measurements. A close approximation is all that can be obtained, even if the most elaborate and intricate formulæ are employed, and it may therefore be considered that the most simple rules should be used for obtaining the heights of mountains.

A description of the method of adjusting and using a mountain barometer will serve as a guide for any of the modifications of this instrument, the principle being in all cases the same.

The mercury is contained in a wooden cistern, or leather bag, at the lower part of the instrument; a screw compresses this mercury, and forces it, when required, up to the upper part of the tube. (By the arrangement of Mr. Newman, this forcing up of the mercury is avoided.) The upper part of the tube is graduated, and, by means of a vernier, the height of the column of mercury may be read to one thousandth of an inch.

Attached to the barometer is a thermometer, which usually reads degrees of Fahrenheit and centrigrade. On the barometer there is usually marked—

N. P., neutral point, . .	29·48
Capacity, ...	$\frac{1}{50}$
Temperature, ...	55°

The neutral point denotes the height of the mercury above zero when the instrument was made. The "capacity," $\frac{1}{50}$, shows that the surface of the mercury in the cistern is 50 times as great as that in the tube, and thus, for every inch of elevation of the mercury in the tube, there will be a depression of $\frac{1}{50}$ of an inch in the cistern. This proportion is found experimentally. A correction is required to be made in connection with the above, and is done as follows :—

If the mercury in the tube should be above the neutral point, the difference between it and the neutral point must be divided by the capacities, and the quotient added to the observed height; the result will be the true height. If, however, at the time of observation, the mercury should be below the neutral point, the difference between the two is to be divided by the capacities, and the quotient must be subtracted from the observed height.

Thus, if the capacities were $\frac{1}{50}$, the neutral point 29·800, and the observed height 30·300, the difference ·5 divided by 50=·01, which, added to the observed height, gives 30·310 for the true height.

If, however, the observed height were 29·300, then the difference ·5, divided by 50, gives ·01 to be subtracted, which would give 29·290 for the true height.

The temperature, 55°, is the assumed mean temperature as a basis for calculation.

There is another correction required for the capillary attraction of the tube; the effect of this attraction is to cause the mercury to be depressed to a cer-

tain amount. This allowance is sometimes marked on the instruments, and is to be added to the former corrections.

The localities where the mountain barometer is most likely to be required in practice are mountainous districts, which are at a distance from the sea. It is just in such situations, however, that very great uncertainty must result from the observations themselves. For, in addition to the personal errors of observation, the effect of the changes in the humidity of the air, and of other causes, will alone produce a change in the height of the mercurial column; and unless two observers, each with an instrument, make observations at the same time, at two localities, considerable uncertainty must result. If it be proposed that one observer is to make observations at the two localities, and is to return to his first station to test whether any change has occurred in the atmosphere during his operations, then it is difficult to avoid the conclusion that the result aimed at, viz., the relative height of two mountains, might probably have been obtained more quickly and more accurately by some other means. By the aid of the pocket-sextant, or the contouring-glass, for instance (both very portable instruments), we might obtain moderately correct results in a very short time. Unless, then, the conditions are highly favourable for observation, it may be doubted whether the mountain barometer is not better as a theoretical than as a practical instrument.

Very elaborate rules have been framed for obtaining heights by the mountain barometer, and allow-

ances have been made for all the supposed disturbing conditions. It is evident that to obtain even moderately accurate results, the temperature of the air and of the column of mercury must be noted and allowed for in the observations at both the stations.

The following formula is found to give very accurate results, and is perhaps as simple as any :—

Make $R = \log \beta - (B + \log. \beta')$ when upper thermometer reads lowest.

Or $R = \log \beta + B - \log \beta'$ when upper thermometer reads highest. Then the log difference in feet between the two stations $= A + C + \log. R$.

These formula must be used in conjunction with the table given at page 189, the method of using which is as follows:—

Find in the column headed "S" the sum of the (Fahrenheit) degrees used on the detached thermometers, at the two stations, and take out the corresponding number from the adjoining column, headed "A;" next, in the column D, find the difference of the degrees used on the attached thermometers, and take out the opposite number in the column B. From the column C, take out the number corresponding to the latitude of the place of observation found in the column L. Then,

When the upper thermometer reads more than the lower:

To the log of the height of the barometer at the lower station, add the number called B, and from their sum subtract the log of the height of the barometer at the upper station, and call the remainder R; then take out the log of R, and add it to

the numbers A and C; and the sum, rejecting tens from the index, will be the logarithm of the difference of altitude in feet between the two stations.

When the upper thermometer reads less than the lower:

Add the log of the height of the barometer at the upper station to the number called B, and subtract their sum from the log of the height of the barometer at the lower station, call the remainder R; then take out the log of R, and add it to the numbers A and C; the sum, rejecting tens from the index, will be the log of the difference of the altitudes of the two stations in feet.

EXAMPLE 1—At the summit of Snowdon, the barometer read 26·409, the detached thermometer 46°, the attached 50°. On Caernarvon quay, the barometer read 30·091, the detached thermometer 60°, the attached 60°. Required, the difference in height between the two stations.

	Upper station.	Lower station.
Detached thermometer . .	46°	60°
Attached ditto	50°	60°
Barometer	26·409	30·091

A = 4·80045 Log of bar. at upper station = 1·4217520
B = ·00043 = ... ·00043

C = 9·99960 1·4221820

Log of bar. at lower station = 1·4784366

R = ·0562546

Then A + C + log R = log of difference of altitudes = 3·55060 = log of 3553 feet.

EXAMPLE 2—Observations were made at Green-

wich Hospital (lower station) and Greenwich Observatory (higher station), the following were the results:—

	Upper station.	Lower station.
Detached thermometer	71°·5	71°·5
Attached ditto	70°·0	70°·0
Barometer	29·870 inches	30·014

Required the difference in height between the two stations. Answer, 136·4 feet.

A very close approximation may be obtained without the use of logarithms, by applying the following formula:—

$$\text{Difference in height} = 55{,}000 \times \frac{B - B'}{B + B'}$$

B, the height of the mercury at the lower station.

B′, " " " " upper "

Add $\frac{1}{440}$ of the result for each degree, by which the mean temperature of the air at the two stations exceeds 55°; substract the like amount if the mean temperature be below 55°*

Taking the preceding examples, we find for No. 1, $55{,}000 \times \frac{B - B'}{B + B'} = 3584$ feet; substracting 16 feet, for difference of thermometers, from 55°, gives 3568 for the result, differing but little from the preceding answer. For No. 2, we have—

$$55{,}000 \times \frac{B - B'}{B + B'} = 132 \cdot 3 \text{ feet.}$$

* When the upper thermometer reads highest, for subtract read "add," and *vice versa*.

Add $\frac{1}{440}$ of result for each degree above $55° = 4·5$ to be added, gives 136·7 feet.

From 89 observations made to ascertain the height of St. Paul's, the results obtained were, by

Galbraith's tables	. . . .	354·30 feet
Ditto formula	. . .	356·40 ,,
General Roy's formula	. .	353·96 ,,

The true height being 352·75.

From 62 observations for the same, the results obtained were—

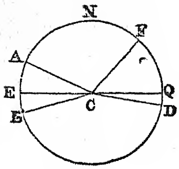
By Galbraith's tables	. . . . .	357·30
,, Ditto formula	. . . .	359·42
,, General Roy's formula	. . .	356·99

By the simple formula given above, the height from the 89 recorded observations would be 354·3, thus showing that incidental errors, even when divided by 62 observations, may give results differing 1 per cent. from the truth; a difference greater than is likely to arise from the application of the simplest formula.

ON FINDING THE LATITUDE BY MEANS OF THE POCKET SEXTANT.

The latitude of any place upon the earth's surface is the angular distance of this place from the equator, measured upon the arc of a circle, which cuts the equator at right angles, and passes through the poles of the earth.

Let N E S Q be a section of the earth, made



through the poles, N and S the north and south poles, E Q the equator; A, B, D, and F, any points upon the earth's surface, C the centre of the earth.

The latitude of A would be measured by the angle A C E and would be called north latitude.

The altitude of B would be measured by the angle E C B, and would be called south latitude. The angle Q C D would be the latitude of D (south) Q C F the latitude (north) of F.

There are several methods by which to obtain the latitude: the most simple only,—viz., by means of a meridian altitude, will be here described. Should a more general knowledge of this portion of the subject be required, the reader is referred to any work upon practical astronomy.

To obtain the latitude by a meridian altitude is so simple an operation, and is likely to be so often useful, either at sea, or in distant colonies, to determine the position of coasts, rocks, mountains, rivers, lakes, &c., that the military traveller ought certainly to devote a few hours to the practice of this problem.

A MERIDIAN ALTITUDE.

The various celestial bodies, *i. e.*, the sun, moon, planets, and stars, rise from the eastern horizon, pass to the south, and set in the west. When any of

these bodies passes to the south, it is then said to be upon the meridian.

When any body is upon the meridian, it then attains the greatest altitude above the horizon, during the twenty-four hours. The sun crosses the meridian each day at twelve o'clock (sun time), but when we estimate time by clocks, the sun will then cross the meridian a few minutes before twelve, and a few minutes after, according to the time of year.

TO TAKE A MERIDIAN ALTITUDE WITH THE SEXTANT.

1st. With the sea or any water as our horizon.

Having ascertained that the sextant is in adjustment, one or both of the coloured glasses should be turned up, so as to intercept the rays of the sun between the two mirrors. The sextant is then held with the screws to the left, and the sight is directed through the clear portion of the horizon-glass to that portion of the horizon which is exactly beneath the sun.

The index-arm is then turned slowly, until the sun becomes visible in the reflecting portion of the horizon-glass.

In this proceeding, care must be taken that the hat, or peak of the cap, or hand, does not intercept the sun's rays from falling upon the index-mirror, and the sextant should be slowly swayed from side to side, so as to catch sight of the sun. The lower

limb of the sun should then be brought to rest upon the sea horizon, which will consequently appear as a tangent to the sun, the sextant being slowly turned from side to side, so that the sun sweeps along the horizon, and never descends beneath it. These preparations should be made a few minutes before the sun passes the meridian.

We should remember in which direction we are obliged to turn the large screw, in order to obtain a greater angle on the graduated arc; and then, as the *greatest* altitude of the sun is required, we should, from the period when we first observed, merely turn the screw in that direction which would give an increase of altitude. Also, we should remember that when the sun appears in the horizon-glass to rise *above* the horizon, *then the sun is rising*, and we must turn the screw so as to keep the horizon a tangent to the sun. The instant that we observe the sun to sink below the sea horizon, then the sun is sinking, and we must not touch the screw that moves the index-arm, as we should then have upon the graduated arc and vernier, the meridian altitude of the sun's lower limb.

Thus, the meridian altitude may be obtained by merely noting when the sun attains its greatest height above the horizon.

Exactly the same method is adopted to obtain the meridian altitude of the moon, a planet, or a star. With the latter two the body itself is observed, the lower limb being undistinguishable from the centre.

THE ARTIFICIAL HORIZON.

An artificial horizon may be formed by any fluid which is capable of reflecting an image, the best liquid being that which is the least influenced by the wind. In cool weather, or in a sheltered position, water, oil, tar, or in fact any fluid may be used. Quicksilver, however, is the best substitute, as it reflects well, and is not so easily agitated by the wind. The surface of the fluid should be protected by a piece of glass, if there should be any wind which is likely to disturb the reflecting surface.

Having arranged the artificial horizon, an observer should place himself so that he can see the sun, or other celestial object, reflected from the artificial horizon, and also see the same object by direct vision. The sextant is then slowly raised, until the object in the artificial horizon is visible through the unsilvered portion of the horizon-glass. The index-arm is then slowly turned until the upper sun is brought as a tangent to the sun seen in the artificial horizon. Some slight practice is required to form this contact readily, but after a few trials no difficulty will be found.

The following rules may be borne in memory, but a few actual observations will soon enable the observer to test practically their truth.

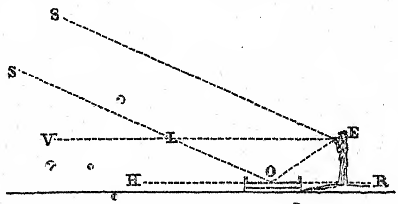
When the upper sun is brought in contact and *above* the sun seen in the artificial horizon, the double altitude of the sun's *lower* limb has been observed.

When the upper sun is brought in contact and *below* the sun seen in the artificial horizon, then the

double altitude of the sun's *upper* limb has been observed.

If this double altitude were 110°, we should then divide this altitude by 2, which would give the observed altitude of the sun's upper or lower limb 55°. The corrections for semi-diameter, refraction, and parallax, should then be made, to obtain the true altitude of the sun's centre.

PRINCIPLE OF THE ARTIFICIAL HORIZON.



Let O be the artificial horizon, the production of the surface H R, being a truly horizontal line. Let E be the position of an observer. From E draw E L V parallel to H O R. Then V L E will be a horizon to the observer at E. Suppose S′ the direction of the sun, then L E S′ will be the altitude of the sun above the horizon. From O, draw O S, parallel to E S′, then the distance O E being as nothing compared to the distance of the sun, O S will be the direction of the sun.

When the image of any body is reflected from a flat surface, the angle of incidence, S O H, is equal to the angle of reflection, E O R. Then, because the lines V E and H R are parallel, and also the

lines E S′ and O S ∴. The angle S L V is equal to the angle S′ E V, and also to the angle L O H. Therefore the angle S′ E V is equal to the angle E O R, because L Q H is equal to E O R. The angle E O R is equal to the angle L E O, because L E and R H are parallel and ∴ the angle L E O is equal to the angle L E S′, consequently the whole angle O E S′ is double the angle L E S′. O E S′ is the angle between the sun and its image, and L E S the altitude of the sun above the horizon. Therefore the angle between the sun and its image is double the altitude of the sun above the horizon.

THE DECLINATION.

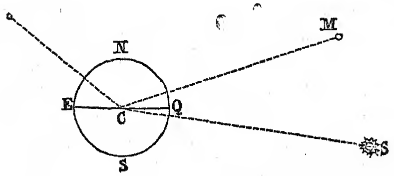
To find the latitude of any place, it is necessary to know the meridian altitude, and also *the declination* of a celestial body.

Declination in the heavens corresponds to latitude on the earth.

The plane of the equator being produced to the heavens is called the equinoctial, and the angular distance of any body from the equator thus produced is called the declination of the body, and is north or south according as the body is north or south of the equinoctial.

Let N E S Q be a section of the earth through the poles, E Q the equator, N and S the north and south poles, C M, C S, and C P, the direction of any three celestial bodies. Then E C P would be

the declination (north) of P, M C Q the declination north of M, S C Q the declination south of S.



The declination of the sun, moon, and planets varies considerably every day, but in the Nautical Almanac, this declination is given for each day of each year. The sun's declination is given upon page 1 of each month, the heading being as follows: The "Apparent Declination," being the column to be noted, as also the south (S) or north (N), before the degrees, &c.

At Apparent Noon.								
Day of the Week.	Day of the Month.	The Sun's				Sidereal time of the semidiampassing the Meridian.*	Equation of time, *to beadded to apparent time.*	Diff. for 1 hour.
		Apparent Right Ascension.	Diff. for 1 hour.	*Apparent* Declination.	Diff. for 1 hour.			
		h m s	s	° ′ ″	″	m s	m s	s
Sat.	1	22 49 12·39	9·345	S.7 30 54·9	57 16	1 5 34	1234·70	0510

The moon is not so convenient as a means of determining the latitude as is a planet or a star.

The declination of each of these bodies may be found, however, under their proper headings, in the same book.

CORRECTIONS TO BE APPLIED TO THE MERIDIAN ALTITUDE.

Having obtained the meridian altitude of the sun's lower limb, we call this altitude "the apparent altitude" of the sun's lower limb. It is, then, necessary to apply three corrections to this observation, to obtain the "*true altitude*" of the sun's centre. These three corrections are for "*semi-diameter*," "*refraction*," and "*parallax*."

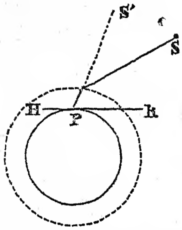
SEMI-DIAMETER.

For convenience, as well as accuracy of observation, the altitude of either the upper or lower limb of the sun is observed, and the true semi-diameter of the sun is then subtracted or added, to obtain the altitude of the sun's centre. The semi-diameter of the sun varies from day to day, according to observations, and its true value is given in the "Nautical Almanac," upon the opposite page to that in which the declination is given. The mean angular distance of the semi-diameter is about 16′.

REFRACTION.

A ray of light from any celestial body, upon enter-

ing the atmosphere, becomes bent in a downwards direction. Thus, if P were any point upon the earth's surface, H R the horizon, and S a celestial object, a ray passing from S would be bent down towards P; and an observer at P would therefore look in the direction P S′, to see S, which would consequently appear more elevated above P R, the horizon, than if there were no such thing as refraction.



The nearer a body may be to the horizon, the greater will be the effect of refraction upon it; when at the zenith, a body will not be affected by refraction.

From long-continued observations, a table of refractions has been generally agreed upon, and, in this table, the corrections which should be applied to each angle is given (see page 192).

N.B.—*The correction for refraction must always be subtracted from observed altitudes.*

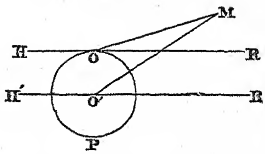
PARALLAX.

When observing with the pocket-sextant, parallax may be neglected, unless we make observation upon the moon, Mars, or Venus, the allowance due to parallax being less, by far, than can be read off the vernier of the sextant. The principle of parallax, however, should be understood.

In order to have some fixed point to which to reduce all celestial observations, it has been

agreed to adopt the centre of the earth as this datum point.

Let O P be a section of the earth, O any point on the surface, H O R the horizon of that point, O′ the datum point at centre of earth, H′ O′ R′ the horizon of this datum, and parallel to H O R. Let M be the moon, or other celestial body, then M O R would be the altitude of the moon, above the horizon H O R; but M O′ R′ would be the altitude above the horizon from the datum O′. It is evident that M O′ R′ is greater than M O R.



N.B.—*Correction for parallax must always be added to observed altitudes.*

The amount due to parallax, at different altitudes, may be found from tables.

CONVERSION OF OBSERVED MERIDIAN ALTITUDES TO TRUE MERIDIAN ALTITUDES.

When the lower limb of the sun has been observed, the angle of altitude is usually written thus—

Obs. merid. alt. $\underline{\odot}$.

When the upper limb, thus—

Obs. merid. alt. $\overline{\odot}$.

The corrections would be as follows:—

EXAMPLE 1—Observed merid. alt. $\underline{\odot}$ 60°, semi-dia. 16′, refraction 33″, parallax 4″. Required, the true meridian altitude of the sun's centre.

Written, true merid. alt. ⊖.

Observed merid. alt. $\underline{\bigcirc}$			60° 0′ 0″	
Semi-dia.	+16′	0″		
Refrac.	— 0′	33″	+0° 15′ 31″	
Parallax	0 0′	4″	60° 15′ 31″	true merid. alt. ⊖.

EXAMPLE 2—Observed meridian alt. $\overline{\bigcirc}$ 40°, semi-dia. 16′, refraction 1′ 8″, parallax 6″. Required true meridian alt. ⊖.

Observed merid. alt. $\overline{\bigcirc}$			40° 0′ 0″	
Semi-dia.	—16′	0″		
Refrac.	— 1′	8″	—17′ 2″	
Parallax	0 0′	6″	39° 42′ 58″	true alt. ⊖.

If we have used the artificial horizon, we should first divide the observed double altitude by 2, and then proceed with the corrections for refraction, parallax, and semi-diameter, exactly as in the preceding examples.

When the sea horizon is used, an allowance must be made for the "dip," according to the height of the eye. Table, p. 190, shows the allowance due to various heights.

CORRECTION REQUISITE TO BE MADE TO THE DECLINATION.

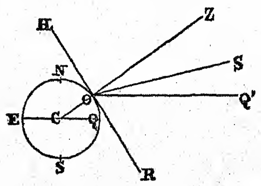
The declination of the sun, &c., given in the Nautical Almanac, is the declination for the meridian of Greenwich. It will be evident that, if the declination of any celestial body vary from day to day, then the declination given for 12 o'clock, at Green-

wich, will not be the true declination for a locality 60° or more, east, or west, of Greenwich. The declination given in the Nautical Almanac requires to be corrected therefore for the longitude. The principle is, that when to the west of Greenwich, and the declination is increasing, we must add the correction due to the longitude; when to the east, subtract. When the declination is decreasing, we must subtract the correction if to the west, and add, if to the east, of Greenwich. A table will give the amount of correction due to the declination, and a little consideration will show in which way this amount is to be applied, to obtain the real declination according to the locality.

We will now proceed to the method of obtaining the latitude by means of a meridian altitude. The declination being given, we will assume that all the corrections have been made, so that we may deal with the true altitude of the sun's centre, and the true declination.

TO OBTAIN THE LATITUDE.

Let N E S Q be a section of the earth through the poles N and S; E Q the equator; C the centre



of the earth; and O any point upon the earth's

surface. Then the angle O C Q will represent the latitude of O.

Join C O, and produce this line to Z, then Z will be the zenith of O.

Draw H O R a tangent to the circle at O, then H O R will be the horizon of O.

From O, draw O Q′ parallel to C Q, then O Q′ will represent the equinoctial of O, because the diameter of the earth may be considered as not producing any angle if viewed from the distant heavens.

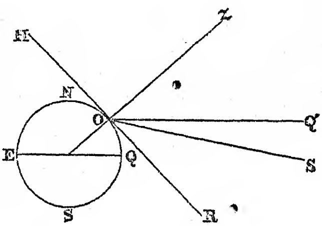
Then, because the lines O Q′ and C Q are parallel, and Z O C cuts them, then the angle Z O Q′ = the angle Z C Q, therefore the angle Z O Q′ is the latitude of O.

Suppose O S the direction of the sun when on the meridian, then the angle S O Q′ will be the north declination of the sun, and S O R the true meridian altitude of the sun, both of which are known quantities, the one being found from the Nautical Almanac, the other measured with the sextant.

Z O Q′ the latitude, is equal to Z O S + S O Q′; and Z O S is equal to 90°—S O R, because Z O R is a right angle. Z O S is called the zenith distance of the sun. S O Q′ being the declination, we therefore have Z O Q′ = Z O S + S O Q′ substituting, we have latitude = zenith distance + the declination.

In the preceding example, the sun and the observer were both upon the same side of the equator. In the next example, the sun is south of the equator, the observer north.

Z O Q′, as before, represents the latitude, O S the direction of the sun, Q′ O S the declination *south* of the sun, R O S will be the meridian altitude of the sun at O; therefore Z O S will be the zenith distance of the sun. Z O Q′ will equal Z O S—Q′ O S that is, the latitude will equal the zenith dis-



tance, *minus* the declination. We thus have the two following formulas:—

First, when the observer and the sun are upon the same side of the equator—

The latitude = the zenith distance + the declination.

When the observer and the sun are upon different sides, then—

The latitude = the zenith distance — the declination.

In all cases, the latitude will take the name of the greater quantity, and will be north or south accordingly. The zenith distance being called north, when the observer's zenith is north of the sun, and south, when his zenith is south.

The rule for obtaining the latitude may be thus summed up :—

RULE—Subtract the *true* meridian altitude from 90°, the remainder will be the zenith distance, which is called north, or south, according as the observer is north or south of the observed celestial body. Take the corrected declination of the observed body, and note whether this is north or south. If the zenith distance and the declination are both north or both south, add the two together; but if one be north, the other south, subtract the less from the greater, and the sum, or difference, will be the latitude north or south, according to the greater term.

EXAMPLE 1. True altitude ⊖ 60°, declination 17° S. Observer south of sun. Required lat.

True alt. ⊖ 60° ∴ Z. D. (zenith distance) = 30° South.
Declination = 17° South.
47° South lat.

EXAMPLE 2. True altitude ⊖ 60°, declination 17° S. Observer north of sun. Required lat.

True altitude ⊖ 60° ∴ Z. D. = 30° North.
Declination = 17° South.
13° North lat.

EXAMPLE 3. The observed meridian altitude $\underline{\bigcirc}$ was 40°. Observer north of sun. Declination 23° S., refraction 1′ 8″, parallax 6″, semi-diameter 16′ 18″. Required lat.

Observed meridian altitude . . .			40° 0′ 0″	
Semi-diameter	+ 16′ 18″	Correction =	+ 15′ 16″	
Parallax	+ 0′ 6″			
Refraction	− 1′ 8″			
			40° 15′ 16″	True alt. ⊖.
			90	
			49° 44′ 44″	Z. D. North.
Declination		=	23° 0′ 0″	South.
			26° 44′ 44″	Lat. North.

The true meridian alt. ⊖ was 30°; observer north of the sun, and, by estimation, in longitude 72° west. The declination for Greenwich on the day of observation was 4° 27′ 0″ north, and, on the day following, 4° 50′ 0″ north. Required the latitude.

The true alt. ⊖ 30° ∴ Z. D. North	=	60° 0′ 0″
Declination for Greenwich 4° 27′ 0″		Declination 4° 31′ 36″ North.
Difference for 24 hours and 360°=23′ 0″		
Then, by proportion, as 360° : 72° : : 23′ : 4′ 36″		Lat. = 64° 31′ 36″ North.
Declination for 72° west ∴=4° 31′ 36″ North		

EXAMPLE 5. Required the latitude in the preceding example, supposing the observer were east of Greenwich.

True alt. ⊖ 30° ∴ Z, D.	=	60° 0′ 0″ North.
The observer being east of Greenwich, the correction, viz., 4′ 36″, should be subtracted from the declination given for Greenwich on the same day. The corrected declination for 72° East longitude would therefore be		4° 22′ 24″ North.
Therefore the latitude	=	64° 22′ 24″ North.

When the observer is to the east of Greenwich, the proportional allowance for longitude should be taken by finding the difference in declination, from the Nautical Almanac, between the day of observation and the day previous. When to the west of Greenwich, between the day of observation and the day subsequent.

If great accuracy should be required, an allowance should be made for the thermometer and barometer, before we use the refraction given in table. Thermometer being 50°, the correction should be *minus* when above and *plus* when below; barometer being 30 inches, the correction is *plus*

when above and *minus* when below. For the pocket-sextant these corrections are not needed, as the instrument will not read to nearer than minutes. Great care should be taken, when measuring an altitude, so that no considerable errors are admitted, and if we have the means at our disposal, the whole of the corrections should be applied.

REMARKS ON THE LATITUDE.

To be able to find the latitude by means of the sextant, is a most useful accomplishment to any officer or traveller. Even as a source of amusement on board ship, or at some out station, far removed from civilization, a knowledge of this subject would amply repay the student for a few hours of labour and thought.

The traveller who may, from either amusement or duty, tread upon ground where few civilized individuals have preceded him, might convert his journey into a scientific expedition, if he would merely take the latitude of any important points, such as mountain peaks, lakes, rivers, villages, &c. If this traveller were unable to find the latitude, still he would be able to afford valuable information were he merely to measure the meridian altitude of the sun at any important places, and note the day upon which their altitudes were obtained. Upon returning from his journey, these observations might soon be converted into latitudes, by competent persons, and thus a map of his course could be constructed.

In cases of shipwreck, when recourse is had to the boats, a pocket-sextant, and the Nautical Almanac might be invaluable, if some individual in each boat would merely remember that

Z D + Dec. = Lat.

It is no great strain upon the memory to bear in mind the declination of one or two of the principal stars, for as the declination of these does not vary *at the most*, more than 1′ in three years, we might, for approximate calculations, be independent of all aid, save that derived from the pocket-sextant. Sirius, for instance, called also Canis Major or the Dog Star, is an excellent star, the declination of which to remember. This star, from its brilliancy, is readily known, besides being pointed at by the three stars of Orion.

The declination (south), of Sirius is 16° 31′, or we might, for rough calculation, call it 16°½. Thus, if we found the altitude of Sirius, as the star crossed the meridian, (*i. e.* the greatest altitude to which the star attained) amount to 40°, and if this star were to our south, then our latitude would be somewhat near 33°½.

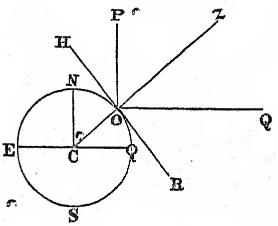
Arcturus is another star which might be used, and is readily found, by drawing a line from the pole star through the last star of the Great Bear, and producing this line. The first large star will be Arcturus, which is about as far from the tail star of the Bear, as is the pole star.

The declination north of Arcturus is about 19° 55 in 1860, and this declination decreases at the

rate of about 19″ annually, or 1′ in about three years.*

If with this star we wished to find our latitude, we proceed as shown in the preceding example.

The pole star also affords a ready means of finding the latitude, for this star is within 1° 27′ of the pole, and the altitude of the pole above the northern horizon is equal to the latitude. This may be readily shown as follows:—



Let N E S Q be a section of the earth, through the poles, and O any point on the surface, N and S the north and south poles; E Q the equator. O Q′ being parallel to C Q, O P parallel to C N.

Then because O Q′ is parallel to C Q, and L C meets these lines, the angle Z O Q′=the angle O C Q, but O C Q is the latitude ∴ Z O Q′ is the latitude. Because O P is parallel to C N, therefore O P is the direction of the pole, and H O R being the horizon ∴ H O P is the altitude of the pole, above the northern horizon.

Z O H, from the zenith to the horizon, is 90°, and

* A list of a few large stars is given at the end of this volume—their declinations being given, and the means of finding them.

P O Q′ from the pole to the equator is 90° ∴ P O Q′=Z O H. Take away the common angle Z O P, and the remainder P O H=Z O Q′, that is the altitude of the pole, is equal to the latitude of the place of observation.

When the pole star is at its greatest altitude, the latitude may be found by subtracting the polar distance of the star from its correct altitude; when the star is below the pole the polar distance should be added to give the latitude. Also if the least and greatest altitudes of any circumpolar star be taken, the mean of these gives the height of the pole, and hence the latitude of the place of observation.

These are merely rough methods by which to approximate to the latitude, when we may happen to be unprovided with any more efficient aid than a pocket-sextant, and when we might be in a situation, where a knowledge of the latitude, to even within thirty miles, might be of the utmost importance. Even neglecting refraction and parallax, we might, by the aid of a star, such as Arcturus, obtain a knowledge of our latitude to within two or three miles, if provided with the pocket-sextant.

It is not always the possession of a large amount of knowledge which is so useful to the soldier, or practical traveller, but the being able to instantly apply a small amount of knowledge, in the manner, and at the time, when it is really required. It is with the conviction that in certain emergencies the preceding expedients might be found

useful, that we have occupied a few lines in order to place them before the reader.

To the colonial surveyor, or to an officer making a military sketch of a large district, the distances of various places may be found by determining the latitudes and longitudes of these stations. In these cases greater accuracy might be required than in the preceding; allowances should therefore be made for barometer, thermometer, &c., and, if possible, the large sextant, or some more accurate instrument, should be used. It is not likely that any individual, who has once found how much amusement there is in following out these subjects, would stop at the alphabet; and consequently if he wishes to enter more deeply into practical astronomy, he should procure some work which treats of more than the mere elements. That which has been mentioned in the preceding pages can all be accomplished with the pocket-sextant, an instrument with which every officer or traveller should be provided.

ADDITIONAL EXAMPLES FOR PRACTICE.

Observed meridian altitude $\underline{\odot}$ 70° 10′; declination 20° 6′ north; refraction 33″; semi-diameter 16′ 10″; observer north of the sun. Required the latitude.

Ans. 39° 40′ 23″ north.

Observed meridian altitude $\overline{\odot}$ 70° 10′; declination 20° 6′ north; refraction 33″; semi-diameter 16′ 10″; observer south of the sun. Required the latitude.

Ans. 0°, 31′, 37″ north.

The observed meridian double altitude of sun's $\odot$

was 90°; refraction 1′; semi-diameter 16′; observation made in longitude 45° west; declination decreasing at the rate of 57″ in one hour; declination for meridian of Greenwich, same day, 3° 17′ north. Required the latitude, the observer being south of the sun. Ans. 41° 30′ 51″ south.

ON FINDING THE LONGITUDE.

The longitude of any place upon the earth's surface is the angular distance at the pole, made by the meridian of this place with another meridian, called the first meridian.

Various nations employ different first meridians. The English consider the meridian of Greenwich their first meridian, consequently the angle made at the pole, between the meridian of Greenwich and the meridian of any other locality, will be the longitude of that other locality.

Longitude is counted east or west, according as the place is east or west of Greenwich, and up to 180°. Thus no place is said to be 190° east or west of Greenwich. If any place were 190° *east* of Greenwich, it would then be said to have 170° *west* longitude.

It will be evident that, as all the meridians meet at the poles, the distance in miles of the degrees of longitude, will vary with the latitude, the distance in miles being greatest at the equator and 0 at the poles of the earth.

In consequence of the earth turning upon its axis every 24 hours, the sun, and all other celestial ob-

jects, will pass to the south of each locality during that period of time. If we consider the motion of the sun uniform (which, however, it is not, as will be explained by and by) we should merely have to observe, when the sun crossed the meridian of the station at which we were, to find when it was exactly 12 o'clock. If, then, we had carried with us, from Greenwich, a chronometer which showed the time at Greenwich, we should then be able to tell the difference of time between our station and Greenwich. Suppose, that when the sun crossed our meridian, it was one o'clock at Greenwich. There would then be one hour's difference of time between the two localities; one hour in time corresponds to 15° in longitude, because 24 hours correspond to 360°. Thus there would be 15° difference in longitude between Greenwich and our station; and our station would be to the west of Greenwich, because the local time was after that of Greenwich.

To obtain the longitude, therefore, it is necessary to compare the time found at any locality with the time at Greenwich; the difference between the local time and the Greenwich time will give the longitude, the rate being 1° of longitude to every four minutes of time. When the local time is after the Greenwich time, the longitude is west; when the local time is before the Greenwich time, the longitude is east.

TO FIND THE GREENWICH TIME.

There are various methods by which to find the

Greenwich mean time. The most common, and that most generally used, is to carry a chronometer which has been tested at Greenwich, and which will always indicate the time shown by a clock at Greenwich. This chronometer usually has a "rate," as it is called—that is, it gains or loses uniformly each day; it is therefore necessary to know the rate, and when the chronometer was set to Greenwich time. Thus, we have merely to add, or to subtract, the rate for the number of days since the chronometer agreed with Greenwich, to find the Greenwich time.

Example :—

A chronometer set to Greenwich time on 1st January, 1860, with a rate of $+2°$ per day, showed 12 hours, 20′, 10″ on the 20th February. What was the Greenwich time at that instant?

50 days at 2″, amounts to 1′ 40″, which, subtracted from the time shown by chronometer, gives 12 hours, 18′, 30″ for the Greenwich time.

GREENWICH TIME BY JUPITER'S SATELLITES.

A very close approximation may be made to the Greenwich time by observing, with an average telescope, the transits or occultations of the satellites of Jupiter. This planet can be observed during nearly eight months of the year, and the Greenwich time at which an occultation, eclipse, transit, &c., occurs, is given at page 487, *et seq.*, of the Nautical Almanac. We have then merely to select one of the eclipses or occultations named for each day, and to watch when

this occurs, to obtain within *at least* one minute the time at Greenwich. When unprovided with a chronometer set to Greenwich time, a traveller may, by the aid of a common watch, approximate closely to Greenwich time, if he checks frequently the rate of his watch, and also tests by means of these phenomena.

Lunar observation—*i.e.*, by measuring the angular distance between the moon and the sun, or a star, is also a means of obtaining Greenwich time. This method is too long to be here described. The first two processes are both simple and practical.

Having found the time shown by a clock at Greenwich, it is then necessary to find the time at the place of observation.

In consequence of the sun moving almost parallel to the horizon when it is on the meridian, we cannot decide, with sufficient accuracy, by means of the sextant, when this event occurs; it is usual, therefore, to measure the altitude of the sun, when this body is about two or three hours from the meridian—thus, at 9 or 10 A.M., or at 2 or 3 P.M.—and we can then find the length of time that will elapse, or has elapsed, since the sun will be or was actually, upon the meridian of the place of observation. The method is as follows:

TO FIND THE LOCAL OR APPARENT TIME.

To find the local time, it is necessary to know the true altitude ⊖ at the time, the latitude of the place of observation, and the declination of the sun.

The true altitude may be found with the sextant as before mentioned; the latitude may be found from the day's meridian observation, adding or subtracting (by estimation) the distance, if any, since travelled; the declination may be found and corrected from the Nautical Almanac, as before explained.

We will now consider what it is that we require, and also with what items we are provided.

We first require to know how far, in angular distance, the sun is from our meridian. Thus, we require to know the angular distance at the pole, which a meridian passing through the sun at the time of observation makes with our local meridian.

We will suppose an individual in the open air when the sun is visible, and we shall then readily understand the problem before us.

If our latitude were 51° north, we should be in angular distance 51° from the equator, consequently 39° from the pole. Thus, the zenith of our locality would be 39° from the pole of the heavens. The distance of the zenith from the pole can always be found by subtracting the latitude from 90°. This distance is termed the *co-latitude.*

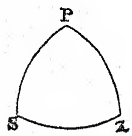
When we know the declination of the sun, we know the distance of the sun from the pole, for the declination subtracted from 90°, will give the *polar distance* of the sun. The co-latitude and the polar distance of the sun would thus form two sides of a spherical triangle.

If we know the altitude of the sun above the hori-

zon, we can find the distance of the sun from our zenith by subtracting the true altitude from 90°.

Thus, we should have the co-latitude, the polar distance of the sun, and its zenith distance, forming three sides of a spherical triangle, one angle of which, viz., the angle at the pole, is the quantity required.

In the triangle P Z S, if P represent the pole, S the sun, and Z the zenith, then P S will represent the polar distance of the sun, = 90°—Declination.



P Z the co-latitude (= 90°—latitude).

S Z the zenith distance of the sun (=90°—the altitude).

Whilst Z P S is the angle required.

When the three sides of a spherical triangle are known, the rule for finding one of the angles is as follows :—

Rule. "Add the three sides, and take half the sum of these, and also the difference between this half sum and the side opposite to the angle sought. Then add the cosecants (or the complements of the sines) of the other sides, to the sines of the half sum, and of the said difference. Half the sum of these 4 logarithms is the cosine of half the angle required."

Having found the angular distance of the sun from the meridian, we can convert this distance into time.

We shall then have found the "sun-time"

or "apparent time" at the place of observation. To convert this apparent time into "*mean time*," we have merely to add or subtract the "equation of time," shown in the column under that head, in the same page of the Nautical Almanac in which the declination is given. Thus, if we found the heading, "Equation of time to be added to apparent time," we should add the allowance due to the day; but if the heading were "Equation of time to be subtracted," then we should subtract.

EXAMPLE 1. Date, 27th January, 1859; apparent time by observation, 10 hours, 6′ 4″. Required equation of time and hence mean time.

Hrs.	M.	S.	
10	6	4	
+	13	0·05	See Nautical Almanac, 1859, January 27.
10	19	4·05	Mean time required.

EXAMPLE 2. 3rd November, 1859; apparent time by observation, 10 hours, 6′ 4″. Required equation of time and hence mean time.

Hrs.	M.	S.	
10	6	4	
−	16	18·11	See Nautical Almanac, 1859, November 3rd.
9	49	45 89	Mean time required.

The sum, or difference, thus found, would give us the *mean time* at the place of observation. This mean time, compared with the Greenwich mean time, will give the difference in time between the two localities, from whence the difference in longitude may be at once obtained.

Time is converted into degrees by converting hours of time into minutes, and, dividing by 4, the quotient is the degrees, minutes, and seconds.

Example 1. 1 hour, 20′ 40″, is 80′ 40″; divided by 4, is 20° 10′.

Example 2. 5 hours, 30′ 20″ is 330′ 20″; divided by 4, is 82° 35′.

To convert degrees, &c., into time, the arc is multiplied by 4. The degrees become minutes of time, the minutes seconds, and the seconds thirds of time.

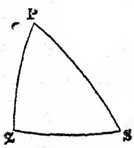
Example 1. 20° 10′, multiplied by 4, is 80′ 40″= 1 hour, 20′ 40″.

Example 2. 82° 35′, multiplied by 4, is 328′ 140″ =5 hours, 30′ 20″.

Examples :—

In latitude 51° north, the true altitude ⊖ was 50°, declination 20° north. Required, the apparent time of the observation which was made after noon.

Let P represent the pole of the heavens, Z the zenith, S the sun. Then, the latitude being 51°, P Z will be 90°—51°=39°. The declination being 20° north, P S will be 90—20=70°. The altitude being 50°, Z S will be 90° — 50° = 40°.



Then Z S=40°
,, P Z=39° cosec=10·2011282
,, P S=$\underline{70°}$ cosec=10·0270142
2)$\overline{149°}$ sum.
½ sum $\overline{74°}$ 30′ sine 9·9839105
Subtract Z S $\underline{40°}$
$\overline{34°}$ 30′ sine $\underline{9·7531280}$

$$\cos.\ \frac{Z P S}{2} = \frac{2)19·9651809}{9·9825904} = \text{cosin } 16°\ 7$$

Therefore Z P S=32° 14.′

Convert 32° 14′ into time, and we have 2 hours 8′ 56″ for the apparent time of the observation.

If the equation of time were 4′ (to be added), we should have 2 hours, 12′ 56″ for the mean time of observation. This mean time, compared with the Greenwich mean time, would give the difference in longitude.

When the sun and the observer are upon different sides of the equator, the cosecant of the supplement of the sun's polar distance must be taken. Also, if the half sum of the three sides be greater than 90°, the sine of the supplement must be taken.

EXAMPLE. In latitude 51° north, the true alt. ⊖ was 20°, declination 15° south. Required the apparent time of observation. Observation made before noon.

$$
\begin{array}{lll}
\text{Alt. } 20^\circ \therefore ZS = & 70^\circ & \\
\text{Lat. } 51^\circ \therefore PZ = & 39^\circ & \text{cosec} = 10{\cdot}2011282 \\
\text{Decl. } 15^\circ S. \therefore PS = & \underline{105^\circ} & \text{cosec} = 10{\cdot}0150562 = \text{cosec } 75^\circ \\
 & 2)\overline{214^\circ} & \\
 & \overline{107^\circ} & \text{sine} = 9{\cdot}9805963 = \text{sine } 73^\circ \\
 & \underline{70^\circ} & \\
 & 37^\circ & \text{sine} = \underline{9{\cdot}7794630} \\
 & & 2)\overline{19{\cdot}9762437} \\
 & & \text{cosec } 13^\circ\, 20' = 9{\cdot}9881218 = \text{cosec } \frac{ZPS}{2}
\end{array}
$$

	hrs.	m.	s.
Z P S = 26° 40′ converted into time =	1	46	40

	hrs.	m.	s.
Apparent time ∴ was	10	13	20

Having obtained the latitude and longitude of several stations in a country, we may construct a map, upon which the relative distances of these stations may be plotted. The degrees of latitude may be considered as of uniform length in miles, when constructing a military map, and the length in miles

of a degree of longitude may be found from a table, the length of each degree in miles varying of course according to the latitude. By setting off the latitude due north or south, and the longitude due east or west, we may obtain several points, which may serve as guides, if we purpose to make a large military sketch of perhaps a hundred miles of country in each direction. The various details may then be added either with the compass or sextant, if these details should be required.

Examples on longitude:—

N. lat. 51°; true alt. ⊖ 40°; dec. N. 20°; equation of time + 6m. 10s.; Greenwich time of observation 2h. 27m. 43s. Required the longitude: observation taken after noon.

Ans. 15° east.

N. lat. 51°; true alt. ⊖ 10°; dec. S. 20°; equation of time—13m. 50s.; time of observation by chronometer, showing Greenwich time, was 3h. 34m. 10s. Required the longitude: observation taken after noon.

Ans. 15° west.

LATITUDE BY MEANS OF THE STARS.

It may happen that, in consequence of clouds, or from other causes, the meridian altitude of the sun cannot be obtained. If, however, we know the apparent time of the observation, we may find the latitude, because we should know the altitude of the sun, the polar distance, and the hour angle. Thus,

in the spherical triangle Z P S, we should know Z S (from zenith to sun), P S (from pole to sun), and the angle Z P S to find the side P Z, or the colatitude. It is here necessary to know the time of the observation, and we are therefore dependent upon a chronometer.

During the night, we may find the latitude approximately by the pole star, or accurately, if provided with the time, the formula being given in the last page of explanations in the Nautical Almanac.

It is advisable that we should know a few of the principal stars, and their declinations, as we could then select that one which was nearest the meridian, and find the latitude by its means.

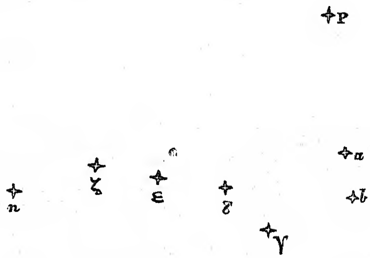
In the following table some stars of the first magnitude are given, and their declinations and positions pointed out:—

STARS' NAMES.	DECLINATION, 1860.	ANNUAL VARIATION.
Aldebaran .	16° 13′ 27″·6 N	+ 7″·6
Capella . .	45° 51′ 2″·7 N	+ 4″·2
Rigel . . .	8° 21′ 59″·9 S	+ 4″·5
Sirius . . .	16° 31′ 38″·1 S	— 4″·6

To find the stars in the heavens, it is necessary to refer to some constellation. That which is best known is the Great Bear, called by its Latin name Ursa Major. This constellation consists of seven

stars, situated as shown below; *a* and *b* are called the pointers, and point to the pole star P.

A line from P at right angles to *a* P, and on the



opposite side to the tail star, will pass through Capella, distant from P about 44°.

A line drawn from the pole star, between Capella and a small star near it to the east, passes just to the west of the constellation *Orion*. The brightest of the two southern stars at the feet of this constellation is Rigel.

About 25° to the north-west of the belt of Orion, and not far from the direction in which it points, is *Aldebaran*, a red star.

A line from *Aldebaran* through the belt passes through *Sirius*, distant about 20° from the belt.

The above-named stars would be found on or near the meridian, *about* midnight, during October to February.

A line from δ to γ, in the great bear, if produced, passes through Regulus.

A line from the pole star through ζ, in the great bear, passes, at 70 distance through Spica.

A line from the pole-star through η, the tail star of the bear, passes, at about 31°, through Arcturus.

STARS' NAMES.	DECLINATION, 1860.	ANNUAL VARIATION.
Regulus . .	12° 38′ 59″·4 N	— 17″·4
Spica . . .	10° 25′ 46″ S	— 18″·9
Arcturus . .	19° 54′ 46″·5 N	— 18″·9
Vega . . .	38° 39′ 20″ N	+ 3″·

A line from Capella through the pole star, if produced, passes through Vega, distant nearly as far upon the opposite side of the heavens.

These stars will pass the meridian during the nights between March and July.

STARS' NAMES.	DECLINATION, 1860.	ANNUAL VARIATION.
α Cygni . .	44° 46′ 54″·2 N	+ 12″·6
Markab . .	14° 27′ 10″ N	+ 19″·3
Fomalhaut .	30° 21′ 47″·9 S	+ 18″·9
Polaris . .	88° 33′ 47″·3	+ 19″

About 23° to the eastward of Vega is α Cygni.

A line from the pointers through the pole, and produced, passes through two bright stars. The first

is called Scheat; the second, Markab. The latter is distant about 75° from the pole star. The same line produced 45°, passes through Fomalhaut. Polaris is the pole star, indicated by the pointers. These stars will pass the meridian during the nights between July and November.

An approximation may be made with the compass to the direction of the meridian, and thus the approximate time of the meridian passage of the star may be found. The altitude may then be measured, either with the artificial horizon, if on shore, or the sea horizon, when the latter is visible. A piece of water, of 100 feet long, may serve as a natural horizon, if we place the eye close to the surface. The latitude may then be found, as detailed for the sun, the refraction being applied to the altitude, as before, semi-diameter and parallax being 0.

A trifling variation takes places at various times of the year, in the declination of the stars, but not sufficient to be noticed, unless minute accuracy is required. This correction is given under the head of the star in the "Nautical Almanac."

The declinations given in the preceding pages will, when the annual variation is applied, according to the years since 1860, serve for average practical purposes, or for a military *sketch* of a large district, or of a coast.

CONCLUDING REMARKS.

HAVING now placed before the reader the various subjects connected with practical sketching, it is merely necessary to remind him, that without practice nothing can be acquired. It is often a subject of annoyance to individuals to find, that, when they attempt to perform any works, which they believed they thoroughly understood, they are beset by difficulties, of which they had no conception. This is a result which will invariably follow the conversion of a mere theorist into a practical man. Many subjects may be accomplished with great ease theoretically, and which, when attempted practically, are found very troublesome. Thus practice is essential. Whilst we endeavour to understand the principles of that which we purpose to do, let us take care that we really can do it.

To make a mere sketch of six or eight miles of country, is, theoretically, the simplest problem in the world; practically, it sometimes, at first, presents difficulties.

Each individual who is desirous, therefore, to qualify himself to make a sketch, should, after a little reading, take either a compass, or a sextant, or even a pencil and a piece of paper, and make a sketch of a small portion of ground. If this portion be only a quarter of a mile square, still it will be a very good beginning; and a larger piece can be attempted afterwards. We must become accustomed to handle the instruments and the sketching-case; for when we have to learn anything at the moment that it is required from us, it can never be either well learned, nor can we depend upon ourselves. If the method of sketching, and of contouring, of making a reconnaissance, or of taking latitude and longitude, or altitudes, be once learnt *from actual practice*, it will never be forgotten. If, however, we merely read about these subjects, a few months will serve to drive them from our memory.

By constant practice and attention, an individual might, in a month or six weeks, make himself complete master of all the subjects which in these pages have been attempted to be simply described.

QUESTIONS.

It sometimes happens that if we have read any elementary work, upon a practical subject, and wish to test the amount of information which we have derived, we experience some difficulty, unless there should be an instructor at hand. I believe the best method to overcome this obstacle is to have certain questions asked, and then to write down answers to these questions, before *referring to the book;* we can then examine ourselves, and will be able to judge which portions of the subject require to be re-studied. It is quite possible, however, that the student may be able to answer a number of questions with great ease, and yet be unable to perform, in practice, even a fractional part of that which he may know theoretically. Thus, he should endeavour first to describe *how* any work should be done, and then proceed to do it. By a judicious combination of practice and theory, any individual may soon become an expert military sketcher.

COMPASS.

		Page.
1.	Explain the method of holding the compass when taking "bearings"	15
2.	What is the difference between bearings and angles?	12

	Page.
3. How would you obtain the angular distance between two objects with the compass?	—
4. Describe the method of "traversing" with the compass	23
5. Show how you could find your own position on a sketch, when you know the position of two or more objects?	25
6. What objects would you select on your sketch for interpolation?	28
7. How would you find the variation of the compass?	36
8. State what objects should be avoided when taking bearings	35
9. If required to sketch a road, what articles would you take, and how would you go to work?	10 & 25

SEXTANT.

	Page.
1. Describe how the vernier of the sextant is used	46
2. Describe how you would adjust the sextant	41
3. State how the sextant should be held when taking vertical angles	43
4. How should the sextant be held when a right-hand object is to coincide by reflection, with the left-hand object, seen by direct vision?	42
6. Suppose that two objects are at an angular distance of about 150°, how can you measure the angle with the sextant, which only reads to about 120°?	50
6. When adjusting the sextant, why should a distant object be selected?	64

MEASURING ALTITUDES.

LATITUDE.

		Page.
2.	If a celestial object happen to be observed, when the object passes between the zenith and the elevated pole, how is the latitude obtained?	154
3.	Supposing the zenith distance and the declination are both north, is the latitude found in the same manner as if the zenith distance is north, and the declination south?	155
4.	State how a correction is made to the declination, for localities east or west of Greenwich	156
5.	Suppose that the declination of a star is not known, how could you obtain the latitude by two observations?	161

LONGITUDE.

		Page.
1.	How can you find the apparent, or sun time, at any place? What data are required?	166
2.	Having found the apparent time, how do you obtain mean time?	169
3.	Knowing the mean time at the place of observation, and knowing Greenwich mean time, how is the longitude thence known?	163
4.	Do you know of any celestial phenomena, by means of which, a close approximation may be made to the longitude, even if you possess only a telescope, a sextant, and a common watch?	165

HILL SKETCHING AND CONTOURING.

		Page.
1.	State one or two methods, by means of which hills may be represented on paper	66
2.	What are the two principal points in hill sketching, and which should be first determined?	65

		Page.
3.	Describe the principle of contouring . .	67
4.	What are impossible contours? Give two or three examples	72 & 73
5.	Give a sketch of a piece of country, and draw some contours, explaining which lines represent steep, and which gradual, slopes, and show where are the hills and where the valleys	—

GENERAL PRINCIPLES.

		Page.
1.	When required to make a military sketch of about six or seven square miles, what should be the first proceeding?	3
2.	When measuring angles, from both ends of a base to surrounding objects, what intersections should be avoided? Show why .	7
3.	How do you extend a system of triangles from a measured base?	5
4.	Describe the instruments employed in surveys of different descriptions	6 & 7
5.	When accuracy is required, which would you do, plot the angles in the field, or calculate the sides of the triangles?	117

SKETCHING WITHOUT INSTRUMENTS.

		Page.
1.	How can you approximate to the distance between two objects, when unprovided with measuring instruments?	81
2.	How can you approximate to angular distances, when unprovided with instruments?	78
3.	By the aid of a piece of rope, how could you obtain the distance of distant objects? .	81
4.	State how, by the aid of a report of a gun, we may approximate to the distance of any object	84

5. Sketch from memory the road between two localities, where you have frequently walked
6. Sketch also the form of the hills near a station, where you have frequently travelled

These two questions (5 and 6) will lead to a habit of observation being adopted, which may be found very useful.

THE THEODOLITE.

	Page.
1. Describe each of the adjustments required by the theodolite	105 to 107
2. Show how a correction is made for index-error, when taking vertical angles . .	109
3. Show how the third angle of a triangle may be obtained, supposing the apex of the triangle is inaccessible	115
4. Show how the theodolite is used for levelling	
5. Show how the theodolite may be employed in connection with the measurement of a base line	130
6. Explain why both verniers should be used when taking horizontal angles . .	111

BAROMETERS.

	Page.
1. What adjustments does the barometer require?	136
2. What difference is made in the calculations, if the higher thermometer reads highest? .	138
3. Give a simple formula for ascertaining the heights by the barometer .	140

EXPLANATION OF TERMS USED.

ALTITUDE—The height of the sun, moon, or stars, or of any object above the horizon, reckoned in degrees, &c., on a vertical great circle.

ALTITUDE MERIDIAN—The altitude of any celestial body when it is on the meridian.

ANGLE—The inclination or opening of two lines, which meet at a point.

ARC—a certain portion of the circumference of a circle.

AZIMUTHS—Great circles which pass through the zenith and nadir, and are perpendicular to the horizon. The azimuth of any celestial object is the arc of the horizon, contained between the east and west point of the heavens, and a vertical circle passing through the centre of that object.

BASE LINE—The foundation of a survey.

BAROMETER—Used to ascertain heights.

BEARINGS—The bearing of an object, is the angle made by two lines, one of which represents the magnetic meridian, and the other is drawn from the object to the other line. Bearings are usually counted from north, round 360°, to north again, thus east is 90° and west 270°.

Chain—Chains used for surveying; Gunter's chain, 66 feet long, divided into 100 parts, called links. The one hundred foot chain, divided also into 100 parts. Gunter's chain is used when areas are to be calculated, because 100,000 square links =one acre.

Collimation—Adjustment for, required in the theodolite.

Compass—Prismatic instrument for taking bearings.

Curvature—Allowance for.

Declination—Is the angular distance of a celestial body, north or south of the equator, measured on a circle at right angles to the equator. Declination in the heavens corresponds to latitude on earth.

Equinoctial—Is the production of the plane of the equator.

Horizon—(sensible) a circle which separates the visible from the invisible hemisphere.

Horizon—(artificial) any fluid or horizontal reflecting surface.

Hour Angle—The angle which a meridian, passing through a body, makes with another meridian.

Latitude—Is the angular distance of any place from the equator, measured on the arc of a great circle, perpendicular to it.

Longitude—Is the angular distance of any place, east or west from a first meridian.

Meridian—A great circle which passes through the nadir, zenith, and poles, and cuts the equator at right angles.

Nadir—The point in the heavens immediately below our feet.

Offsets—Measurements made at right angles to a chain line; offsets are measured with a staff ten links long. They should not be taken beyond 100 links.

Parallax—(celestial). The difference between the position of any object seen from the surface and centre of the earth.

PARALLAX—(of the sextant). The difference in the angle, between two objects, when seen from the index-mirror, or eye-hole of the sextant.

POLAR DISTANCE—The distance of any object from the pole.

REFRACTION—The effect produced upon a ray of light passing through the air.

SEXTANT—Instrument used for taking angles.

TIME—(apparent). The time shown by the sun.

TIME—(mean). The time shown by a clock.

TIME—(equation of). The difference between the sun time, and the mean time, at the same locality.

THEODOLITE—Instrument used in accurate surveys.

VARIATION—(of compass). The angular difference between the true, and the magnetic meridian.

ZENITH—The point of the heavens directly over head.

ZENITH DISTANCE—The angular distance of any body from the zenith.

CONVERSION OF DEGREES INTO TIME.

ARC.						TIME							
°	H. M.	′	M. S.	″	S.	H.	°	M.	° ′	S.	′ ″	10th	″
0	0 0	0	0 0	0	0·0	0	0	0	0 0	0	0 0	0·0	0·0
1	0 4	1	0 4	1	0·1	1	15	1	0 15	1	0 15	0·1	1·5
2	0 8	2	0	2	0·1	2	30	2	0 30	2	0 30	0·2	3·0
3	0 12	3	0 12	3	0·2	3	45	3	0 45	3	0 45	0·3	4·5
4	0 16	4	0 16	4	0·3	4	60	4	1 0	4	1 0	0·4	6·0
5	0 20	5	0 20	5	0·3	5	75	5	1 15	5	1 15	0·5	7·5
6	0 24	6	0 24	6	0·4	6	90	6	1 30	6	1 30	0·6	9·0
7	0 28	7	0 28	7	0·5	7	105	7	1 45	7	1 45	0·7	10·5
8	0 32	8	0 32	8	0·5	8	120	8	2 0	8	2 0	0·8	12·0
9	0 36	9	0 36	9	0·6	9	135	9	2 15	9	2 15	0·9	13·5
10	0 40	10	0 40	10	0·7	10	150	10	2 30	10	2 30	1·0	15·0
11	0 44	11	0 44	11	0·7	11	165	11	2 45	11	2 45		
12	0 48	12	0 48	12	0·8	12	180	12	3 0	12	3 0		
13	0 52	13	0 52	13	0·9	13	195	13	3 15	13	3 15		
14	0 56	14	0 56	14	0·9	14	210	14	3 30	14	3 30		
15	1 0	15	1 0	15	1.0	15	225	15	3 45	15	3 45		
16	1 4	16	1 4	16	1·1	16	240	16	4 0	16	4 0		
17	1 8	17	1 8	17	1·1	17	255	17	4 15	17	4 15		
18	1 12	18	1 12	18	1·2	18	270	18	4 30	18	4 30		
19	1 16	19	1 16	19	1·3	19	285	19	4 45	19	4 45		
20	1 20	20	1 20	20	1·3	20	300	20	5 0	20	5 0		
30	2 0	21	1 24	21	1·4	21	315	21	5 15	21	5 15		
40	2 40	22	1 28	22	1·5	22	330	22	5 30	22	5 30		
50	3 20	23	1 32	23	1·5	23	345	23	5 45	23	5 45		
60	4 0	24	1 36	24	1·6	24	360	24	6 0	24	6 0		
70	4 40	25	1 40	25	1·7			25	6 15	25	6 15		
80	5 20	26	1 44	26	1·7			26	6 30	26	6 30		
90	6 0	27	1 48	27	1·8			27	6 45	27	6 45		
100	6 40	28	1 52	28	1·9			28	7 0	28	7 0		
110	7 20	29	1 56	29	1·9			29	7 15	29	7 15		
120	8 0	30	2 0	30	2·0			30	7 30	30	7 30		
130	8 40	31	2 4	31	2·1			31	7 45	31	7 45		
140	9 20	32	2 8	32	2·1			32	8 0	32	8 0		
150	10 0	33	2 12	33	2·2			33	8 15	33	8 15		
160	10 40	34	2 16	34	2·3			34	8 30	34	8 30		
170	11 20	35	2 20	35	2·3			35	8 45	35	8 45		
180	12 0	36	2 24	36	2·4			36	9 0	36	9 0		
		37	2 28	37	2·5			37	9 15	37	9 15		
		38	2 32	38	2·5			38	9 30	38	9 30		
		39	2 36	39	2·6			39	9 45	39	9 45		
		40	2 40	40	2·7			40	10 0	40	10 0		
		41	2 44	41	2·7			41	10 15	41	10 15		
		42	2 48	42	2·8			42	10 30	42	10 30		
		43	2 52	43	2·9			43	10 45	43	10 45		
		44	2 56	44	2·9			44	11 0	44	11 0		
		45	3 0	45	3·0			45	11 15	45	11 15		
		46	3 4	46	3·1			46	11 30	46	11 30		
		47	3 8	47	3·1			47	11 45	47	11 45		
		48	3 12	48	3·2			48	12 0	48	12 0		
		49	3 16	49	3·3			49	12 15	49	12 15		
		50	3 20	50	3·3			50	12 30	50	12 30		
		51	3 24	51	3·4			51	12 45	51	12 45		
		52	3 28	52	3·5			52	13 0	52	13 0		
		53	3 32	53	3·5			53	13 15	53	13 15		
		54	3 36	54	3.6			54	13 30	54	13 30		
		55	3 40	55	3·7			55	13 45	55	13 45		
		56	3 44	56	3·7			56	14 0	56	14 0		
		57	3 48	57	3.8			57	14 15	57	14 15		
		58	3 52	58	3·9			58	14 30	58	14 30		
		59	3 56	59	3·9			59	14 45	59	14 45		

FOR DETERMINING ALTITUDES WITH THE BAROMETER.

Computed by Mr. Baily's Formula XXXVIII.

Thermometers in open Air.						Thermometers to the Barometers.		Latitude of the Place.	
S	A	S	A	S.	A	D	B	L	C
°		°		°		°		°	
40	4·76891	84	4·79019	128	4·81048	0	0·00000	0	0·00117
41	·76940	85	·79066	129	·81093	1	·00004	3	·00116
42	·76989	86	·79113	130	·81138	2	·00009	6	·00114
43	·77039	87	·79160	131	·81183	3	·00013	9	·00111
44	·77089	88	·79207	132	·81228	4	.00017	12	·00107
45	4·77138	89	4·79254	133	4·81272	5	0·00022	15	0·00101
46	·77187	90	·79301	134	·81317	6	·00026	18	·00095
47	·77236	91	·79348	135	·81362	7	·00030	21	·00087
48	·77286	92	·79395	136	·81407	8	·00035	24	·00078
49	·77335	93	·79442	137	·81451	9	000·39	27	·00069
50	4·77383	94	4·79488	138	4·81496	10	0·00043	30	0·00059
51	·77433	95	·79535	139	·81541	11	·00048	33	·00048
52	·77482	96	·79582	140	·81585	12	·00052	36	·00036
53	·77531	97	·79629	141	·81630	13	·00056	39	·00024
54	·77579	98	·79675	142	·81675	14	·00061	42	·00012
55	4·77628	99	4·79722	143	4·81719	15	0·00065	45	0·00000
56	·77677	100	·79768	144	·81763	16	·00069	48	9·99988
57	·77726	101	·79814	145	·81807	17	·00074	51	·99976
58	·77774	102	·79860	146	·81851	18	·00078	54	·99964
59	·77823	103	·79907	147	·81896	19	·00083	57	·99952
60	4·77871	104	4·79953	148	4·81940	20	0·00087	60	9·99941
61	·77920	105	·79999	149	·81983	21	·00091	63	·99931
62	·77968	106	·80045	150	·82027	22	·00096	66	·99922
63	·78017	107	·80091	151	·82072	23	·00100	69	·99913
64	·78065	108	·80137	152	·82116	24	·00104	72	·99905
65	4·78113	109	4·80183	153	4·82160	25	0·00109	75	9·99899
66	·78161	110	·80229	154	·82204	26	·00113	78	·99893
67	·78209	111	·80275	155	·82248	27	·00117	81	·99889
68	·78257	112	·80321	156	·82291	28	·00122	84	·99886
69	·78305	113	·80367	157	·82335	29	·00126	87	·99884
70	4·78353	114	4·80412	158	4·82379	31	0·00130	90	9·99883
71	·78401	115	·80458	159	·82422	30	0·00134		
72	·78449	116	·80504	160	·82466				
73	·78497	117	·80549	161	·82510				
74	·78544	118	·80595	162	·82553				
75	4·78592	119	4·80641	163	4·82597				
76	·78640	120	·80687	164	·82640				
77	·78688	121	·80732	165	·82683				
78	·78735	122	·80777	166	·82726				
79	·78783	123	·80823	167	·82770				
80	4·78830	124	4·80869	168	4·82813				
81	·78878	125	·80914	169	·82857				
82	·78925	126	·80958	170	·82900				
83	·78972	127	·81003	171	·82943				
84	4.79019	128	4·81048	172	4·82986				

S = the sum of the detached thermometers at the two stations.

D = the difference of the attached thermometers at the two stations.

L = the latitude

β = height of the barometer at the upper station.

β' = height of the barometer at the lower station.

Make R = log. β — (B + log. β') when upper thermometer reads lowest,

Or R = log. β + B — log. β' when upper thermometer reads highest.

Then the log. diff. of altitude in English feet = A + C + log. of R.

CORRESPONDING THERMOMETERS,
Fahrenheit, Centigrade, Reaumur.

F.	C.	R.	F.	C.	R.
°	°	°	°	°	°
0	—17·8	—14·2	60	15·6	12·4
1	—17·2	—13·8	61	16·1	12·9
2	—16·7	—13·3	62	16·7	13·3
3	—16·1	—12·9	63	17·2	13·8
4	—15·6	—12·4	64	17·8	14·2
5	—15·0	—12·0	65	18·3	14·7
6	—14·4	—11·6	66	18·9	15·1
7	—13·9	—11·1	67	19·4	15·6
8	—13·3	—10·7	68	20·0	16·0
9	—12·8	—10·2	69	20·6	16·4
10	—12·2	— 9·8	70	21·1	16·9
11	—11·7	— 9·3	71	21·7	17.3
12	—11·1	— 8·9	72	22·2	17·8
13	—10·6	— 8·4	73	22·8	18·2
14	—10·0	— 8·0	74	2·33	18·7
15	— 9·4	— 7·5	75	23·9	19·1
16	— 8·9	— 7·1	76	24·4	19·6
17	— 8·3	— 6·7	77	25·0	20·0
18	— 7·8	— 6·2	78	25·6	20·5
19	— 7·2	— 5·8	79	26·1	20·9
20	— 6·7	— 5·3	80	26·7	21·3
21	— 6·1	— 4·9	81	27·2	21·8
22	— 5·6	— 4·4	82	27·8	22·2
23	— 5·0	— 4·0	83	28·3	22·7
24	— 4·4	— 3·6	84	28·9	23·1
25	— 3·9	— 3·1	85	29·4	23·6
26	— 3·3	— 2·7	86	30·0	24·0
27	— 2·8	— 2·2	87	30·6	24·4
28	— 2·2	— 1·8	88	31·1	24·9
29	— 1·7	— 1·3	89	31·7	25·3
30	— 1·1	— 0·9	90	32·2	25·8
31	— 0.6	— 0.4	91	32·8	26·2
32	0	0	92	33·3	26·7
33	0·6	0·4	93	33.9	27.1
34	1·1	0·9	94	34·4	27·6
35	1·7	1·3	95	35·0	28·0
36	2·2	1·8	96	35·6	28·4
37	2·8	2·2	97	36·1	28·9
38	3·3	2·7	98	36·7	29·3
39	3·9	3·1	99	37·2	29·8
40	4·4	3·6	100	37·8	30·2
41	5·0	4·0	101	38·3	30·7
42	5·6	4·4	102	38·9	31·1
43	6·1	4·9	103	39·4	31·6
44	6·7	5·3	104	40·0	32·0
45	7·2	5·8	105	40·6	32·4
46	7·8	6·2	106	41·1	32·9
47	8·3	6·7	107	41·7	33·3
48	8·9	7·1	108	42·2	33·8
49	9·4	7·5	109	42·8	34.2
50	10·0	8·0	110	43·3	34·7
51	10·6	8·4	111	43·9	35·1
52	11·1	8·9	112	44·4	35·5
53	11·7	9·3	113	45·0	36·0
54	12·2	9·8	114	45·6	36·4
55	12.8	10·2	115	46·1	36·9
56	13·3	10.7	116	46·7	37·3
57	13·9	11·1	117	47·2	37·8
58	14·4	11·6	118	47·8	38·2
59	15·0	12·0	119	48·3	38·7
60	15·6	12·4	120	48·9	39·1

APPARENT DIP OF THE SEA HORIZON.

Height of Eye.	Dip.
0	0′ 0″
1	1 0
2	1 20
3	1 40
4	2 0
5	2 10
6	2 20
7	2 40
8	2 50
9	3 0
10	3 10
12	3 20
14	3 40
16	4 0
18	4 10
20	4 20
22	4 30
24	4 50
26	5 0
28	5 10
30	5 20
35	5 50
40	6 10
45	6 50
50	7 0
55	7 20
60	7 40
65	8 0
70	8 10
75	8 30
80	8 50
85	9 0
90	9 20
100	9 50
110	10 20
120	10 50
130	11 20
140	11 40
150	12 10
160	12 30
170	12 50
180	13 10
190	13 40
200	14 0
210	14 20
220	14 40
240	15 10
260	15 50
280	16 30
300	17 0

MEAN ASTRONOMICAL REFRACTION.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°)

App. Alt.	Refrac.	D. to 10′	App. Alt.	Refrac.	D. to 10′	App. Alt.	Refrac.	D. to 10′	App. Alt.	Refrac.	D. to 10′
° 0′	34′ 17″	″ 122	6° 1′	8′ 18″	″ 12	12° 50′	4′ 11″	″ 3·2	35° 0	1′ 23″·2	″·50
10	32 15	112	15	8 12	12	13 0	4 8	3·1	30	1 21·7	·50
20	30 23	102	20	8 6	11	10	4 5	3·1	36 0	1 20·2	·47
30	28 41	94	25	8 1	11	20	4 2	3·0	30	1 18·8	·47
40	27 7	86	30	7 56	11	30	3 59	3·0	37 0	1 17·4	·47
50	25 41	78	35	7 50	11	40	3 56	2·9	30	1 16·0	·47
1 0	24 22	73	40	7 45	10	50	3 53	2·9	38 0	1 14·6	·43
10	23 9	67	45	7 40	10	14 0	3 50	2·8	30	1 13·3	·43
20	22 2	62	50	7 35	10	10	3 47	2·7	39 0	1 12·0	·43
30	21 0	58	55	7 30	10	20	3 45	2·6	30	1 10·7	·42
40	20 2	53	7 0	7 25	9	30	3 42	2·5	40 0	1 9·5	·40
50	19 9	49	5	7 20	9	40	3 40	2·5	41 0	1 7·1	·38
2 0	18 20	46	10	7 16	9	50	3 37	2·4	42 0	1 4·8	·35
10	17 34	44	15	7 11	9	15 0	3 35	2·4	43 0	1 2·6	·34
15	17 12	42	20	7 7	9	10	3 32	2·3	44 0	1 0·4	·34
20	16 51	40	25	7 3	9	20	3 30	2·2	45 0	0 58·4	·33
25	16 31	39	30	6 59	9	30	3 28	2·2	46 0	0 56·3	·32
30	16 11	38	35	6 54	9	40	3 25	2·1	47 0	0 54·4	·31
35	15 52	37	40	6 50	8	50	3 23	2·1	48 0	0 52·6	·30
40	15 34	36	45	6 46	8	16 0	3 21	2·1	49 0	0 50·7	·29
45	15 16	35	50	6 42	8	10	3 19	2·1	50 0	0 49·0	·28
50	14 59	34	55	6 38	8	20	3 17	2·1	51 0	0 47·3	·27
55	14 42	33	8 0	6 35	8	30	3 15	2·0	52 0	0 45·6	·26
3 0	14 26	32	5	6 31	7	40	3 13	2·0	53 0	0 44·0	·26
5	14 10	31	10	6 27	7	50	3 11	2·0	54 0	0 42·0	·25
10	13 55	30	15	6 23	7	17 0	3 9	1·9	55 0	0 40·9	·25
15	13 41	29	20	6 20	7	30	3 3	1·9	56 0	0 39·4	·25
20	13 27	28	25	6 16	7	18 0	2 58	1·8	57 0	0 37·9	·24
25	13 13	27	30	6 13	7	30	2 53	1·7	58 0	0 36·5	·24
30	13 0	26	35	6 9	7	19 0	2 48	1·6	59 0	0 35·1	·23
35	12 47	25	40	6 6	6	30	2 44	1·5	60 0	0 33·7	·22
40	12 34	25	45	6 3	6	20 0	2 39	1·4	61 0	0 32·4	·22
45	12 22	24	50	6 0	6	30	2 35	1·3	62 0	0 31·0	·22
50	12 10	24	55	5 57	6	21 0	2 31	1·2	63 0	0 29·8	·21
55	11 58	23	9 0	5 54	6	30	2 27	1·2	64 0	0 28·5	·21
4 0	11 47	22	5	5 51	6	22 0	2 24	1·1	65 0	0 27·2	·20
5	11 36	21	10	5 48	6	30	2 20	1·1	66 0	0 26·0	·20
10	11 26	21	15	5 45	6	23 0	2 17	1·0	67 0	0 24·8	·20
15	11 15	20	20	5 42	6	30	2 13	1·0	68 0	0 23·6	·20
20	11 5	20	25	5 39	6	24 0	2 10	1·0	69 0	0 22·4	·20
25	10 55	19	30	5 36	5	30	2 7	0·9	70 0	0 21·3	·20
30	10 46	19	35	5 33	5	25 0	2 5	0·9	71 0	0 20·1	·20
35	10 37	18	40	5 31	5	30	2 2	0·9	72 0	0 19·0	·19
40	10 28	18	50	5 25	5	26 0	1 59	0·9	73 0	0 17·9	·19
45	10 19	18	10 0	5 20	5	30	1 56	0·9	74 0	0 16·7	·18
50	10 10	17	10	5 15	5	27 0	1 54	0·8	75 0	0 15·7	·18
55	10 2	16	20	5 10	5	30	1 51	0·8	76 0	0 14·6	·18
5 0	9 54	16	30	5 6	5	28 0	1 49	0·8	77 0	0 13·5	·17
5	9 46	16	40	5 1	5	30	1 47	0·7	78 0	0 12·4	·17
10	9 38	15	50	4 56	4	29 0	1 45	0·7	79 0	0 11·3	17
15	9 30	15	11 0	4 52	4	30	1 43	0·7	80 0	0 10·3	·17
20	9 23	15	10	4 48	4	30 0	1 41	0·7	81 0	0 9·2	·17
25	9 16	14	20	4 44	4	30	1 39	0·6	82 0	0 8·2	·17
30	9 9	14	30	4 40	4	31 0	1 37	0·6	83 0	0 7·2	·17
35	9 2	14	40	4 36	4	30	1 35	0·6	84 0	0 6·1	·17
40	8 55	13	50	4 32	4	32 0	1 33	0·6	85 0	0 5·1	·17
45	8 48	13	12 0	4 28	4	30	1 31	0·6	86 0	0 4·1	·17
50	8 42	13	10	4 25	4	33 0	1 30	0·6	87 0	0 3·1	·17
55	8 36	12	20	4 21	4	30	1 28	0·5	88 0	0 2·0	·17
6 0	8 30	12	30	4 18	4	34 0	1 26	0·5	89 0	0 1·0	·17
5	8 24		40	4 14		30	1 25		90 0	0 0	

TABLE TO CORRECT THE SUN'S DECLINATION.

When Declin. is increasing,	add in W. Long. sub. in E. Long.	When Declin. is decreasing,	sub. in W. Long. add in E. Long.

SUN'S DECLINATION.

Long.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	23½°	Long.
°	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′			′	′	′	°
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	10
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	20
30	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	0	30
~~40~~	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	0	40
50	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	1	1	1	0	50
60	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	1	1	0	60
70	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	2	2	2	1	0	70
80	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	3	3	3	2	2	1	0	80
90	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	4	4	4	4	3	3	2	1	0	90
00	7	7	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	4	4	4	3	2	1	0	100
110	7	7	7	7	7	7	7	7	7	7	7	6	6	6	6	6	5	5	5	4	4	3	3	1	0	110
120	8	8	8	8	8	8	8	7	7	7	7	7	7	7	6	6	6	6	5	5	4	4	3	2	0	120
130	8	8	8	8	8	8	8	8	8	8	8	8	7	7	7	7	6	6	6	5	5	4	3	2	0	130
140	9	9	9	9	9	9	9	9	9	9	8	8	8	8	7	7	7	6	6	6	5	4	3	2	0	140
150	10	10	01	10	10	10	10	9	9	9	9	8	9	8	8	8	7	7	6	6	5	5	4	2	0	150
160	10	10	10	10	10	10	10	10	10	10	10	9	9	9	9	8	8	7	7	6	6	5	4	2	0	160
170	11	11	11	11	11	11	11	10	10	10	10	10	10	9	9	9	8	8	7	7	6	5	4	2	0	170
180	12	12	12	12	12	12	11	11	11	11	11	11	11	10	10	9	9	8	8	7	6	5	4	2	0	180

UNITED SERVICE INSTITUTION
OF INDIA, NEW DELHI
LIBRARY
Acc. No. M. 608
Dated 15-9-64

CAMDEN PRESS, LONDON.

United Service Institution of India
Library

Acc. No. M6081
Class No. 358.271 Book No. DRA
Author Drayson
Title Practical Military Surve
~~Inf and Sketching~~

5219

United Service Institution of India

Library

* Books drawn by a member can be retained for one month and renewed once, provided no other member requires them.
* New books must be returned within two weeks.
* Not more than two books may be on loan at the same time.
* Members are prohibited from transferring books to other members.
* Members will be required to pay full price with penalty of any book lost or damaged by them.
* Reference and Rare books are not allowed to be taken out of the Library.
* Books are liable to be recalled when in special request.